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by
Peter N. Johnson and Scott P. Robertson

Research Report #206

May 1981

YALE UNIVERSITY
DEPARTMENT OF COMPUTER SCIENCE

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The importance of intention in conversation has been considered by many researchers in artificial intelligence and psychology. However, most models of conversation have been limited to pursuing the transfer of knowledge between the system and a user. We propose that conversational goals can address communication at a number of other levels such as the conversats' emotions, their relationship, and their attitudes. MAGPIE (Multiple Active Goal Processor in Interactive Exchanges) is a computer model of a conversant

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that acquires and pursues conversational goals at a number of levels, including the goal of seeking dominance in it's relationship with the other conversant. At the heart of the program is a set of tracking procedures, each of which monitors a specific level of communication flow in a conversation. These procedures are coupled with a conversational goal planner which generates responses that simultaneously pursue a number of goals. Currently, MAGPIE is able to model a wife during a short marital dispute with her husband. Normative data form human subjects is presented which supports the conversational goals proposed in our analysis.

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MAGPIE: A Goal-Based Model of Conversation

by

Peter N. Johnson and Scott P. Robertson

Abstract

The importance of intention in conversation has been considered by many researchers in artificial intelligence and psychology. However, most models of conversation have been limited to pursuing the transfer of knowledge between the system and a user. We propose that conversational goals can address communication at a number of other levels such as the conversants' emotions, their relationship, and their attitudes. MAGPIE (Multiple Active Goal Processor in Interactive Exchanges) is a computer model of a conversant that acquires and pursues conversational goals at a number of levels, including the goal of seeking dominance in it's relationship with the other conversant. At the heart of the program is a set of tracking procedures, each of which monitors a specific level of communication flow in a conversation. These procedures are coupled with a conversational goal planner which generates responses that simultaneously pursue a number of goals. Currently, MAGPIE is able to model a wife during a short marital dispute with her husband. Normative data from human subjects is presented which supports the conversational goals proposed in our analysis.

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1. Introduction

1.1 Conversation as a Process

Conversation is a process in which people participate purposefully. In order for computer programs to carry on general dialogs with people they must first be able to understand the purposes under which people operate in conversation. Furthermore, a complete model of a conversant must not only infer the conversational goals of others, but must act in accordance with its own goals as well.

The issue of intention in conversation has been addressed by other dialog researchers. [Allen and Perrault 80], [Carbonell 78], [Mann, Moore, and Levin 77], and [Grosz 77] for example, have all made substantial progress. There seem to have emerged two (often overlapping) approaches to modelling the intentional aspect of dialogs:[1]

- to develop systems in keeping with the speech act paradigm (i.e. that interpret speech acts as planning elements for pursuing conversational goals),

- to develop systems that operate in task-oriented domains, relying on cooperation between the conversants to pursue a common goal.

While both of these approaches have met with some success, the scope of conversational intentions that have been considered has

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[1]An exception to this categorization is Carbonell's MICS system, which operates on more general conversational goals. As an example, one of its goals is to "learn about the person to whom it is conversing."

remained somewhat limited. People participate in conversation with a wide range of purposes. In everyday dialogs, conversants are certainly not limited to addressing each other's knowledge states, as has been the case with most computer models. Likewise, their conversational goals are not limited to seeking and transferring information about the world. The research described in this paper is an effort to explore a wider variety of conversational goals. The questions we are asking are:

- What types of conversational goals are there?

- How are conversational goals acquired and monitored in the course of a dialog?

- How do people pursue their conversational goals while participating in a dialog?

In pursuing these questions (among others), we have developed a process model of a conversant. This model has been implemented in a computer program called MAGPIE and is being tested for psychological validity in a series of experiments. (See section 4.)

1.2 MAGPIE: A Computer Program for Conversation

MAGPIE is a computer program that has been developed to simulate the cognitive tasks that a human performs in the course of participating in a conversation. The program is intended to actually carry on dialogs with other conversants in much the same way that people do. Thus, it is capable of initiating a dialog for its own purposes, responding to statements made by other conversants, bringing up new (and relevant) information, and acquiring new conversational goals as the dialog

proceeds. Most importantly, the conversational goals dealt with in MAGPIE are not limited in scope to the transfer of information at the knowledge state level alone. It is this aspect of the program that we will emphasize in this paper.

The overall goal in developing the MAGPIE program is to fully specify a general model for the process of participating in conversation. It is hoped that eventually the MAGPIE program will be able to converse in a reasonable manner on any topic within a domain that it has knowledge of. (What it means for MAGPIE to have knowledge of a domain should become clear.)

An immediate goal of this research has been to provide the MAGPIE program with the capability of simulating the wife in a specific hypothetical husband-wife conversation. This particular conversation originally appeared in Schank and Lehnert [Schank and Lehnert 79] and is repeated below.

<wife home alone last night, husband out somewhere>
W0: Why were you out so late last night?

H1: I went bowling with the boys.
W1: I thought you hated bowling.

H2: It's ok when I have some company.
W2: Aren't I company?

H3: It's not the same.
W3: Sure, because you can't pick up women at home.

H4: I don't pick up women at the bowling alley.
W4: Well, who says you go to the bowling alley?

H5: If I told you that's where I was, that's where I was.
W5: Then how come you smelled of perfume last night?

H6: What perfume? That was smoke.
W6: It sure was a funny kind of smoke.

H7: Well maybe it was.
W7: You'll get arrested if you do that in a bowling alley.

H8: We didn't do it in a bowling alley.
W8: Then where were you last night?

H9: All right. I was at Joe's house. We had a few beers and smoked some dope. I didn't want to tell you because I know you can't stand Joe.
W9: Liar! And hanging out with that creep. I want a divorce.

Currently, the program is capable of conversing as the wife through approximately the first half of this dialog.[2] (A detailed trace of the program running on the second exchange is shown in section 5.) At some points, MAGPIE is also able to generate additional responses that could

[2]Although MAGPIE is designed to interact with existing parser and generation programs at Yale, we have not yet actualized the connections. Thus the program currently employs extended conceptual dependency representations [Schank 75] for input and output.

serve as alternatives to the wife's statements above. A few of the alternatives generated by MAGPIE for the first few statements are shown below:

W0: Why were you out so late last night?
W0-a: Where were YOU last night?
W0-b: Why weren't you home last night?

W1: I thought you hated bowling.
W1-a: You're lying, you don't bowl anymore.
W1-b: The last time you went bowling, you said
you had such a miserable time that you'd
never go again.

At first glance, this husband-wife conversation does not appear to be particularly complicated. After all, it seems typical of the kind of verbal disputes that occur between most married couples at one time or another. However, a closer examination reveals that many complex issues and problems arise in modelling the wife throughout the dialog. In the next section, a few of these issues (which made developing the MAGPIE program difficult) will be outlined. It is because this dialog is both typical and illustrative of many problems that it was chosen as our initial target for our research.

1.3 Some Issues in Modelling Conversation

In order to uncover some of the issues in modelling a conversant, we will make an initial pass through the first three exchanges in the husband-wife dialog and point out just a few of the problems that arise. The focus here will be on the wife's perspective in the conversation.

<wife home alone last night, husband out somewhere>
W0: Why were you out so late last night?

The initial circumstance before the conversation had begun was that

the wife had found herself home alone. Certainly she still proceeded to do many things anyway such as eating dinner, reading a book, watching television, and so on. The next morning, she started this conversation by addressing her husband's absence the night before. Why did she decide to focus on this rather than on some other aspect of the previous evening? Or put another way, what did she hope to gain by starting the conversation this way?

This illustrates a general problem in conversation initiation. Why do people decide to start conversations? In this particular case, the wife brings up the events that occurred the night before. When people bring up events, how do they decide which aspects of the events to focus on? The wife could have started a very different conversation with the line "I watched Love Story on television last night." What difference in circumstance might have lead her to use this opening line rather than the other?

H1: I went bowling with the boys.
W1: I thought you hated bowling.

On the surface, the husband seems to be simply answering his wife's question. But the wife doesn't seem to be satisfied with this response, since she challenges it in her next statement. What is it about his statement that bothers her? If the answer to this is that he is lying, then how does the wife decide that he is lying? Also, given that she decides he is lying, why does she decide to call him on it?

In both of her first two statements (and throughout the conversation), the wife chooses to aggressively challenge the

acceptability of her husband's actions. On what basis should a conversation program elect to make accusations of wrongdoing rather than decide to politely ask for explanations?

Also, notice that she pursues several goals simultaneously with her response. Not only does she seek new information, but she expresses anger and realizes an accusation of wrongdoing as well. All of this is accomplished with a single question.

H2: It's ok when I have some company.
W2: Aren't I company?

What does the word "company" mean in this context? How is the general notion of companionship to be represented in the computer? The wife reacts to her husband's statement as a emotional jab directed against her. Why? What does she know about their relationship that causes her to react this way?

The conversation as a whole seems to have a consistent theme. The wife continuously badgers her husband with accusations while he tries to maintain an air of innocence by consistently ignoring or denying these accusations. The dialog seems to reach a natural termination point when he is finally backed into a corner and must admit to his wrongdoing. But even when he does admit, he tries to justify it in terms of saving her grief.

A model of conversation must not only deal with the problem of making reasonable responses to individual statements, but it must deal with this issue of global consistency as well. What is the feature of conversation that accounts for this global consistency?

An answer to this last question follows from the observation that people usually participate in a conversation in accordance with some general purpose. In the husband-wife dialog, the wife feels that her husband has failed to fulfill an obligation associated with their marriage. This unfulfilled obligation is taken as a challenge to her level of dominance in the relationship. The wife's purpose in the conversation is to regain some of this lost dominance. Thus, each statement that she makes not only reflects a smooth transition from what her husband has just said, but is a function of this overall conversational goal as well.

This brings us back to the questions about conversational intention that we asked at the beginning of the paper. How are conversational goals acquired, monitored, and pursued in the course of participating in a dialog? Pursuing these questions provided the impetus for developing the conversation algorithm that is introduced in the next section.

1.4 An Overview of an Algorithm for Conversation

The starting point of this research was an observation by Schank and Lehnert [Schank and Lehnert 79] that there are many levels of information flow when two people engage in conversation. Not all communication takes place at the surface of the actual dialog. In most situations, there is a great deal of communication going on beneath the surface as well. The full conceptual content of each individual statement can only be determined if all active levels of information flow are continuously monitored.

Schank and Lehnert originally proposed twelve levels of communication to which a surface statement can be decomposed. Their analysis was motivated by the realm of alternative responses that can be made at specific points to "turn" the conversation in a number of different directions. By choosing to respond at certain levels and not at others, a conversant may attempt to control the direction of the conversation.

The motivation behind our analysis is somewhat different. In building taxonomy of communication levels, we hope to provide a framework for the operation of conversational goals. This entails both the acquisition of new goals, the monitoring of existing goals, and the planning to pursue several goals simultaneously. Our somewhat modified set of conversational levels is enumerated below:

1. KNOWLEDGE STATE: At any given point, a conversant has an episodic memory representation of the events that are under discussion. Conversational goals at this level attempt to fill in gaps in the conversant's understanding of these events.

2. KNOWLEDGE STATE (OF OTHER): A conversant must also have a representation of what the other conversant(s) knows about the events under discussion. This is especially important when explaining things to other people. Goals at this level seek to fill in gaps (or avoid doing so) in the other conversant's understanding.

3. EMOTIONS: While they are generally involuntary, emotions still have an important effect on how a conversant will respond in a conversation. Extreme emotional feelings can completely dominate the formation of a response. At this level, a conversant seeks to express his emotions.

4. EMOTIONS (OF OTHER): Statements often reveal the emotions of the other conversant(s). Conversational goals at this level seek to detect and/or modify the emotions of the other conversant.

5. TRUTH AND TRUST: The other conversant may not be telling the truth. Capturing another person in a lie may be very important, as it is in the husband-wife conversation. Goals at this level try to verify that claims made by the other conversant really reflect his knowledge state.

6. RELATIONSHIP: This is the level at which statements are analyzed for their effect on the relationship between the conversants. Goals at this level seek to change the relationship along certain dimensions. (This level is discussed at length in the next section.)

7. BELIEFS: The support structure behind a person's opinions may be called into play during a conversation. Goals at this level arise in arguments in which a conversant seeks to defend his beliefs. (This level addresses the support

structure for the representations at levels 1 and 2.)

8. BELIEFS (OF OTHER): Another person's beliefs are often revealed as presuppositions in his statements. In arguments, goals at this level seek to change the other conversant's beliefs.

9. ATTITUDES: A conversant's attitudes toward objects, activities, and even people may be affected by a statement another has made. At this level, a conversant seeks to express his attitudes.

10. ATTITUDES (OF OTHER): A statement may implicitly or explicitly reveal the attitudes of the other speaker. Typically a salesman, for example, has the goal at this level of getting others to like his product.

At the heart of the conversation algorithm embodied by the MAGPIE program are procedures for tracking these levels of information flow. Tracking the levels provides a source of conversational goals. Pursuing these goals, in turn, leads to the generation of a motivated response. This general process is outlined below:

1. ANALYZE THE INCOMING STATEMENT AT EACH OF THE ACTIVE LEVELS

2. ADD ANY RESULTING NEW GOALS TO THE EXISTING ONES

3. PURSUE THE GOALS BY EMPLOYING CONVERSATIONAL STRATEGIES TO GENERATE A RESPONSE

4. EXPRESS THIS RESPONSE IN A NATURAL LANGUAGE

In the target husband-wife conversation (section 1.2), many conversational goals arise as the participants detect conflict in the communication. By conflict, we mean that the conversants detect inconsistencies in the statements made by others. Such inconsistencies center around many of the levels we have listed above. For example, at the knowledge state level, the wife detects an inconsistency in the husband's claim to have been bowling. This in turn may give rise to a knowledge seeking goal to explain the inconsistency. At the truth and trust level, the wife decides that her husband is lying. Such lying is then determined to be inconsistent with their marriage at the relationship level. Married people are supposed to tell the truth to each other. Thus, a conversational goal to regain lost dominance is subsequently produced at the relationship level.

Detecting inconsistencies at each of the levels is one means by which new conversational goals may be acquired. The mechanism that we use to do this is the conversational trace point (CTP). A CTP is a focus marker placed on the representation generated at a particular level whenever an inconsistency is detected at that level. Each CTP

corresponds to one of the precategorized types of inconsistencies that may arise in the course of tracking a communication level. CTPs in turn organize rules that can result in the production of new conversational goals whenever they are instantiated during a conversation.

As an example, two of the CTPs instantiated while processing "I went bowling with the boys" are PLAN INCONSISTENCY (from the knowledge state level) and ATTITUDE INCONSISTENCY (from the relationship level). The first of these generates a knowledge seeking goal to explain the inconsistency. The second generates a dominance seeking goal in response to the lie detected by the truth and trust tracker. Pursuing these new goals and an already existing dominance seeking goal ultimately results in the response: "I thought you hated bowling." This example is sketched in Figure 1-1, and will be described in more detail in 2.3.

In the next section, we will spell out in some detail the specific procedures for tracking two of the conversational levels: the knowledge state level and the relationship level. Both of these levels are particularly crucial in the husband-wife conversation. The emergence of CTPs during these tracking procedures will also be discussed.

Section 3 will deal with the task of pursuing conversational goals in order to generate a response. A taxonomy of conversational goals in which categories index sets of strategies will be presented. The focus of the planning algorithm is to generate responses that simultaneously pursue many of the conversational goals rather than just one.

```
I went bowling with
     the boys

       ||
       ||
       \/
                                             New
  TRACKING LEVELS      Conversational  Conversational
   OF INFORMATION       Trace Points        Goals
 +---------------+    +-------------+  ***********   Existing
 |KNOWLEDGE STATE|    |    Plan     |==>*  KS-    *  Conversational
 |      x---------->  |Inconsistency|  *  SEEK    *       Goals
 +---------------+    +-------------+  ***********    ***********
 |EMOTIONS       |                                    * D-REL    *
 |               |                                    *dominance*
 +---------------+                                    ***********
 |TRUTH & TRUST  |                                         *
 |      x----------<lie>---+                               *
 +---------------+         |                               *
 |    . . .      |         |                               *
 |               |         |                               *
 +---------------+    +-------------+  ***********         *
 |RELATIONSHIP   |    |  Attitude   |==>* D-REL    *       *
 |      x---------->  |Inconsistency|  *dominance* * * * *
 +---------------+    +-------------+  ***********

                                              ||
                                              ||
                                              ||
                                              ||
                                           PLANNING
                                              ||
                                              ||
                                              \/
                                         Conversation
                                            Action
                                      +---------------+
                                      |  ACCUSATION   |
                                      |               |
                                      +---------------+
                                         ||
                                     GENERATION
                                         ||
                                         \/

                                  "I thought you
                                   hated bowling"
```

Figure 1-1: PROCESS SKETCH

Section 4 outlines the results from experiments that we have

conducted to measure the psychological validity of our model Finally, a detailed trace of the MAGPIE program producing the response "I thought you hated bowling" (corresponding to Figure 1-1) is presented and discussed in section 5. Section 6 briefly describes our conclusions from this work and discusses some possible directions for future research.

2. Tracking Conversational Levels

Participating in conversation is usually a multifaceted task. For not only do people engage in dialogs to exchange information, but they seek to affect each other in a number of other ways as well. Conversational goals range from persuasion and empathy to catharsis and the modification of the conversants' relationship. In the section 1.4, we outlined ten levels for characterizing the communication flow in a conversation. The utility of these levels is twofold: to decompose the conceptual content of conversants' statements and to organize the goals under which people operate during a dialog.

In keeping with this scheme, the MAGPIE program monitors its conversations along each of the ten levels. This is accomplished by employing specialist algorithms associated with each of these levels. In the actual implementation, the procedures interact with each other in a variety of ways. For example, the truth and trust tracker must recognize when the knowledge state tracker has noticed an intentional non sequitur (as is the case when the husband claims to have been bowling). For simplicity, we will consider the levels to be independent.

The problem of determining which levels are active in a given conversation is discussed briefly in Schank and Lehnert [Schank and Lehnert 79]. Certainly most of the levels are tracked to at lease some extent in all conversations. The problem becomes one of determining how deep to process each level. The levels that seem particularly crucial

in the husband-wife dialog (knowledge state, relationship, attitudes, and emotions) are probably tracked deeply in all conversations between intimate people. In general, this question of level activation remains an open problem that will not be discussed further in this paper.

Each tracking algorithm has three responsibilities:

- REPRESENTATION: to generate a representation of the conversation at its corresponding level,

- GOAL GENERATION: to generate CTPs (when appropriate) which may lead to new conversational goals,

- GOAL MONITORING: to monitor the status of existing conversational goals at the corresponding level, pursuing those that have not yet been achieved.

Goal monitoring is part of the planning process that will be discussed in section 3.

Two tracking algorithms which are crucial in processing the husband-wife conversation are the knowledge state tracker and the relationship tracker. These algorithms will be described in some detail in the next two subsections. Keep in mind that these procedures must satisfy the above three responsibilities at their corresponding levels of communication, although we will only focus on the first two for the time being.

2.1 Tracking at the Knowledge State Level

Tracking at the knowledge state level entails analyzing incoming statements for their information content with respect to the situations and events that are under discussion. At the beginning of the husband-wife conversation, for example, the couple is discussing an alleged incident of bowling on the part of the husband. The wife is tracking at the knowledge state level to fill in gaps in her understanding of this incident.

This example is typical. A large part of many everyday conversations is spent discussing episodes that the conversants have either experienced or heard about.[3] At the knowledge state level, conversants discuss the details of such episodes. Thus the notion of what constitutes an episode is the key issue that the knowledge state tracker must address. Our working definition is as follows:

> Episode Definition
>
> An episode is a causally or intentionally related sequence of scene instances. A scene instance groups together a set of actions with a common time, a common place, and generally a common goal.[4] Episodes and scenes together make up the dialog representation at the knowledge state level.

The details of what goes into a scene instance will be discussed later. The important point here is that we are tracking two types of

---

[3]The authors have taped several conversations in various settings including restaurants, classrooms, and offices. In each case, several specific episodes were discussed.

[4]This is very similar to Schank's definition of a scene [Schank 81]. The difference is that Schank was referring to a knowledge structure. In using the term scene instance, we refer to partial instantiations of such structures created dynamically as a dialog proceeds.

information with respect to episodes: physical and intentional. Tracking physical information is the task of fitting described events together into a cohesive causal chain. A causal chain here is a construction adopted from Schank [Schank 73] referring to a causally connected set of primitive actions and states.[5] As an example, the act of lifting a bowling ball RESULTS in the state of holding the ball which ENABLES the act of rolling the ball down a lane, and so on. RESULTS and ENABLES are two primitive casual connections between acts and states in Schank's theory of causal representation.

Tracking intentional information entails monitoring the goals and plans of the characters in each episode under discussion. An intentional explanation is sought for each action, plan, and goal described during the conversation using the scheme originated by Wilensky [Wilensky 78] and formalized by Dyer [Dyer and Lehnert 80]. Basically, the task is to find the plans implemented by specified events, the goals intending these plans, and the themes originating the goals. Themes, goals, and plans are discussed at length in Schank [Schank and Abelson 77]. In the target conversation, the wife determines that bowling is a recreational activity in service of an entertainment goal.

The algorithm for accomplishing all of this is primarily one of memory search. As new episodes are introduced, the knowledge state

---

[5]Actions and states are representing using conceptual dependency theory. [Schank 75].

tracker must access generalized knowledge about the activities under consideration. This generalized knowledge is captured in knowledge *structures* coupled with specific memories from which the generalizations were made. (The content and organization of these knowledge structure in memory will be discussed later.) Tracking at the knowledge state level when new episodes are created is basically a problem of searching memory to find the appropriate knowledge structure.

Thus, the first step in understanding "I went bowling with the boys" is to access the bowling and the recreation knowledge structures in memory. These structures will provide the information necessary to form the physical and intentional explanations discussed earlier. As the appropriate knowledge structures are found, they are linked to an episode (EP) node which is created to represent the new episode. EP nodes correspond to partial instantiations of several interrelated knowledge structures. (This is similar to the BORIS episodic memory representation scheme [Lehnert, Dyer, Johnson, Yang, and Harley 81].) These nodes are further broken down into scene instances.

An example is diagrammed in Figure 2-1.

Knowledge structures such as those for bowling and recreation have associated expectations about the generalized events that they represent. For example, the bowling knowledge structure has expectations about the reasons people bowl, about the actions involved in a game of bowling, and the location at which people bowl. (The bowling knowledge structure will be discussed in detail later.) When a

```
+---------------+          +---------------+
|   BOWLING     |          | RECREATION    |
|  KNOWLEDGE    |          | KNOWLEDGE     |
|  STRUCTURE    |          | STRUCTURE     |
|               |          |    *          |
+-----------*---+          +----*----------+
            *                   *
            * * *           * * *
                *   EP1   *
             +--*----------*------+
             | BOWLING EPISODE    |------+
             |  Bowlers:          |      |
             |   <husband>        |     EP1
             |   <friends>        |  EXPECTATION
             +--------------------+    AGENDA
               *         *         *
       * * * *          SC2        * * * * *
       *            +------------------+     *
.. CHECK-IN..       |-setting-         |  .. PAYING ..
   SCENE            | loc: ALLEY1      |     SCENE
  INSTANCE          | time: <evening>  |    INSTANCE
                    | events:          |
                    |   EV-BOWLING0    |
                    |     --+$BOWL--   |
                    +------------------+
```

Figure 2-1: BOWLING EPISODE: This shows the representation created at the knowledge state level for "I went bowling with the boys."

knowledge structure is adjoined to a specific EP node, its expectations are placed on an agenda that is associated with that EP node. Thus, EP nodes not only declaratively represent what is known about an episode, but they also hold expectations about what yet might be discovered.

The knowledge state level representation of the conversation consists of EP nodes (and corresponding SCENE INSTANCE nodes) like the ones described above. Statements that provide additional information about previously introduced episodes are understood by searching through existing EP nodes and executing the associated agendas. So, if the husband mentions later in the conversation that he won, then a bowling

expectation will trigger to add this information to the bowling episode.

Thus we see that tracking at the knowledge state is driven by the process of memory search. As new episodes are introduced, relevant knowledge structures are sought. And as existing episodes are discussed, existing EP nodes are searched and their associated agendas of expectations are executed. The overall knowledge state tracking algorithm is flowcharted in Figure 2-2.

The first step in the algorithm is conceptual analysis (or parsing). This refers to the decoding process by which natural language input is converted into an extended conceptual dependency (CD) representation.[6] A complete discussion of conceptual analysis would be beyond the scope of this paper. (Refer to [Lehnert, Dyer, Johnson, Yang, and Harley 81] for a description of the parser that MAGPIE is designed to work with.)

As suggested by the flowchart in Figure 2-2, there are three cases that must be handled in the post-parsing phase of the knowledge state tracker:

---

[6]The extensions to CD to which we refer follow as a natural consequence of the theory that parsing and memory search must be integrated processes. [Schank 80]. If, for example, in parsing "John went shopping .." the shopping script ($SHOPPING) is accessed, then the parser would produce:

```
($SHOPPING
   #SHOPPER <john>
   EVENT (PTRANS
           ACTOR  <john>    FROM  <nil>
           OBJECT <john>    TO    <store>))
```

Knowledge State Tracker

```
                      +----------------------+
                      |      Conceptual      |
                      |       Analysis       |
                      +----------+-----------+
                                 |
                      +----------------------+
                      | Was a knowledge      |
              +-------| structure accessed?  |--------+
              |       +----------------------+        |
             yes                                      no
              |                                       |
        +---------------------+                       |
        |   Is it already     |                       |
   +----|  linked to an EP    |----+    +----------------------+
   |    |in this conversation?|    |    |   Search through     |
   |    +---------------------+    |    |  existing EP nodes   |
  yes                              no   |   on the basis of    |
   |                               |    | recency (and usage); |
+----------------+    +----------------+ |    Execute their     |
| Execute the    |    | Generate a new | |associated expectation|
| EP's agenda    |    | EP; bring in   | |       agendas        |
+----------------+    | expectations   | +----------------------+
        |             | from knowledge |            |
        |             |   structure    |            |
        |             +----------------+            |
        |                     |                     |
        |             +----------------+            |
        |             |  Execute the   |            |
        |             |  EP's agenda   |            |
        |             +----------------+            |
        |                     |                     |
        +---------------------+                     |
                  |                                 |
                  +---------------------------------+
                                 |
                                 |
                                end
```

Figure 2-2: KNOWLEDGE STATE TRACKING ALGORITHM

1. NEW EPISODE: The parser accessed a knowledge structure that is completely unrelated to any existing episodes. This happens in the husband-wife conversation when understanding "I went bowling with the boys." In this case, a new episode (EP) node is created and the expectations associated with the

knowledge structure are placed on the new node's expectation agenda.

2. OLD EPISODE (ACCESSED): The parser accessed a knowledge structure already linked to an existing episode in the conversation. In this case, the other conversant is probably providing additional information about the episode in question. This new information is extracted and included in the episode representation by executing the EP expectation agenda.

3. OLD EPISODE (UNACCESSED): The parser generated a CD representation of the statement without accessing any knowledge structures. If bottom up rules are unsuccessful in reaching a knowledge structure directly, then all existing EP nodes are searched (by recency of usage) until the statement is explained. As each EP node is traversed, its corresponding expectation agenda is executed.

This describes the control structure of the knowledge state tracker. But recall that the task at hand is to find a physical and an intentional explanation of the events under discussion. How does the algorithm accomplish this task?

The answer to this of course lies in the content portion of the procedure: the expectation execution. In form, episode agenda expectations are similar to the parsing expectations of Riesbeck [Riesbeck 75]. That is to say, they are basically test-action pairs in

which the expected condition is tested and the corresponding action is performed on success. Often, the action is to instantiate the portion of the knowledge structure that has been recognized in the test. In addition to the test-action pair, episode expectations also contain a strength-else pair. The strength is another test which is evaluated ONLY if the expectation condition is not met. It determines if the expectation is strong enough that it's failure should be noticed. If so, it performs the actions specified in the else portion of the expectation. This is crucial to the generation of CTPs, which will be discussed in section 2.3.

The core of the knowledge state tracker is the set of rules embodied by episode expectations. These rules procedurally apply the information represented declaratively in the knowledge structures. Thus they may be explicated by examining the content of these knowledge structures.

The most important type of structure that the knowledge state tracker employs is the MOP (Memory Organization Packet, from Schank [Schank 79]). A MOP serves to represent generalized knowledge that people have abstracted from similar episodes and situations that they have encountered. People are able to learn from experience by generalizing across similar episodes to form MOPs (Lebowitz, [Lebowitz 80]). Each MOP resides in memory intertwined with some of the specific episodes that contributed to its formation.

Before discussing a specific example of some MOPs used while

tracking at the knowledge state, some elaboration on how MOPs are represented is in order. MOPs are comprised of three basic *components:*[7]

1. PHYSICAL COMPONENT -- This corresponds to the generalized sequence of events that take place in episodes organized under the MOP along with space/time constraints on the scenes that these episodes occur in. The sequence of events is represented as a causal chain of primitive actions and states. For simple MOPs, this component is captured by a script (Schank and Abelson [Schank and Abelson 77], Cullingford [Cullingford 78]). In more complicated situations, the causal chain for an episode is formed dynamically as a specialization of a more general MOP or combination of MOPs.

2. INTENTIONAL COMPONENT -- This corresponds to an intentional explanation of the events in the MOP from the perspective of each of the roles involved. Each role's goals are represented along with the plans that these goals intend and the actions that realize the plans. Again, the intentional explanation of all but very simple episodes is not captured

[7]The description of MOPs in this section is greatly simplified. In their most recent incarnation [Schank 81], MOPs consist of an ordered sequence of generalized SCENEs. In this current theory, the three components that we are attributing to MOPs would actually belong to the generalized scenes pointed to by MOPs. These scenes are shared by several MOPs, enabling one to learn across specific contexts. So what we will be describing in this section is actually the bowling scene, not the bowling MOP. The distinction is not important for our purposes here, but it will be discussed in section 5.

in one MOP. Most episodes are explained by the dynamic combination of a number of general MOPs.

3. EPISODIC ACCESS COMPONENT -- This consists of a set of indices to specific episodes organized under the MOP. Episodes that are very similar to the generalized sequence of events, etc. captured by the above two components are not likely to be indexed by this access structure. Such mundane episodes are likewise not liked to be remembered in this scheme. It is the episodes that deviate in some way from the generalization that are indexed. An example of this from the husband-wife conversation is presented below. The structure itself consists of discrimination trees hung from portions of the MOP components described above. The discriminations in the trees are based on deviations between the generalization and the episode(s) being indexed.

MOPs are linked to one another in a network by MOP-LINKs. A MOP-LINK not only joins two MOPs, but it specifies how the causal chains and intentional explanations in the two MOPs overlap one another. This allows general MOPs to have constrained variables for goals, states, actions, etc. as well as for roles. For example, the specific type of service exchanged in a CONTRACT MOP can be represented as an ACTION variable. These variables can either be filled by mop-link specifications from more specific MOPs (like perhaps a PROFESSIONAL-SERVICE MOP) or by actions from specific episodes.

We proposed above that knowledge structures for bowling and recreational activities are necessary to understand "I went bowling with the boys." In addition to these, a more general structure for sporting activities could also be called into play. Thus the knowledge structure network sketched in Figure 2-1 (page 20) could be actually realized by three MOPs: M-BOWLING, M-RECREATION, and M-SPORTING-ACTIVITIES.

M-BOWLING captures knowledge that people have generalized from various the episodes of bowling that they have experienced. This includes specific knowledge about bowling alleys, the sequence of actions involved in bowling, the rules of bowling, and so on. The access structure from this MOP indexes various interesting bowling episodes like "the time I bowled 300", "the time my husband really had a rotten time," and "the time I got the 7-10 split." These episodes are interesting by virtue of their being different from the norm.

The more general MOPs, M-RECREATION and M-SPORTING-ACTIVITIES, consist primarily of intentional information. M-RECREATION organizes activities performed for relaxation and entertainment. M-SPORTING-ACTIVITIES organizes activities performed for exercise. This scheme is outlined in Figure 2-3 below.

The roles for the MOPs are shown along with some of the goals comprising the intentional component. E-ENTERTAINMENT (in M-RECREATION) is an enjoyment goal and A-PHYSIQUE is an achievement goal. These goal types fit into the general goal taxonomy proposed by Schank and Abelson [Schank and Abelson 77]. The importance of these categories will be

```
    M-RECREATION                              M-SPORTING-ACTIVITIES
+--------------------------------+       +---------------------------+
| RECREATOR                      |       | SPORTSMAN                 |
|* * E-ENTERTAINMENT             |       | * * A-PHYSIQUE            |
|*    |                          |       | *    |                    |
|*   intends                     |       | *   intends               |
|*    |                          |       | *    |                    |
|*    +--÷> ?ACTIVITY            |       | *    +--÷> ?SPORT         |
|*             *                 |       | *             *           |
+*-------------*-----------------+       +-*-------------*-----------+
 *             *                           *             *
 * * * * * * * * * * * * * * * * * * * * * *             *
 * *           *                                         *
 * *           *         M-BOWLING                       *
+*-*-----------*-----------------------------------------*-----------+
|* *           *                                         *           |
|* * BOWLER-A  * * * *    BOWLER-B                       *      ...  |
|* ** ?G-BOWL---+    *      ---                          *      ---  |
|       |       |    *                                   *           |
|       |   intends * * * *   * * * * * * * * * * * * * *           |
|       |       |          *   *                                     |
|       |       +------÷>EV-BOWLING                                  |
|       |                $BOWLING                                    |
|       |                 <outcome staté>                            |
|       |                       |                                    |
+------÷|----------------------÷|-----------------------------------+
        |                       |
       / \                     / \
      / \                         \
       / \                       / \
          \                         \
         EP67                      EP21
    +----------------------+  +----------------------+
    | <bowling>            |  | <bowling>            |
    | HUSBANDO             |  | WIFEO                |
    |    E-ENTERTAINMENT   |  |    ...               |
    |   status: FAILED     |  |   $BOWLING           |
    |                      |  |    <score 300>       |
    |       .....          |  |       .....          |
    +----------------------+  +----------------------+
```

Figure 2-3: BOWLING CONFIGURATION: A knowledge structure configuration for bowling is shown.[8] EP67 is an episode in which the husband had a bad time. EP21 is an episode in which the wife bowled 300.

demonstrated by goal-attitude constraints which will be discussed later.

---

[8]Again, in the most recent incarnation of MOP theory, what we are calling M-BOWLING would actually be a scene, not a MOP.

The casual chain comprising the physical component is represented as a script in this case, $BOWL. The action and goal variables are prefaced by "?"s.

Two episodes are shown as possible interesting deviations from the general bowling scheme. One of these, EP67, is indexed by a planning failure on an entertainment goal of the husband. This corresponds to "the time my husband really had a rotten time." EP21 is indexed by an extreme slot binding in the bowling script. This corresponds to "the time I bowled 300." It should be noted that specific episodes organized around a MOP can bring additional, more specific expectations to the task of knowledge state tracking. For example, if the wife bowls 300 again and is reminded of EP21, she may make predictions on the basis of what specifically happened before. So if in EP21 she ended up getting her name in the paper, she may expect this to happen again.

MOP structures such as this embody the rules that drive the knowledge state tracking process. Naturally, these rules are associated with the MOP components that organize them. Thus, there are rules organized around roles, goals and planning, MOP events, and and settings (time and place).

ROLE RULES

Role rules consist of class restrictions and character stereotypes. Class restrictions are requirements on the type of entity that can fill a given MOP role. These are broad categories based upon the conceptual analysis hierarchy tree. Objects are broken down in this tree as animate/inanimate, human/animal, male/female, and so on. The only

restriction on a bowler is that he (she) be human.

Character stereotypes, to the extent that they exist for a given MOP, organize rules for behavior around more obscure features. Violations of characters matching these features are usually feasible, but sometimes seem quite strange. As an example, the wife may have thought her husband facetious had he responded to his wife's initial question with:

H1: I went bar hopping with my grandmother.

Researchers in psychology have also been concerned with the process of applying character stereotypes (eg. Hastie and Kumar [Hastie and Kumar 79], Cantor [Cantor and Mischel 79]). Their results suggest that such stereotypes do indeed effect the process of inference making during understanding. Schank and Lebowitz [Schank and Lebowitz 79] propose a scheme in which character stereotypes are analyzed across various planning dimensions such as their energy and ability in pursuing plans. Each role can be rated along these dimensions for each of its goals in the MOP. This information can be applied to predict behavior for MOP characters in much the same way that Schank and Lebowitz used it to predict behavior for characters in interpersonal theme roles. Thus, a voracious bowler is one who is likely to apply a lot of energy towards pursuing a bowling entertainment goal.

In the MAGPIE project, the following simple nominals features for analyzing characters have also proven to be useful:

- ERA: This represents a time period in a person's general life

cycle.[9] Nominal values include CHILDHOOD, TEEN-YEARS, YOUNG-AGE, MIDDLE-AGE, OLD-AGE.

- SE-STATUS: This indexs the socioeconomic status of a person. Nominal values include POOR, LOWER-MIDDLE, MIDDLE, UPPER-MIDDLE, RICH.

- EDUCATION: Nominal values include DROP-OUT, HIGH-SCHOOL, COLLEGE, PROFESSIONAL.

This set only begins to enumerate some of the features that can be used to characterize people. The important point is that features such as these accumulate for each character as he plays different roles in various episodes. Contradictions in features are often noticed. When this happens, the apparent contradiction can easily become a topic in the conversation. (Using contradictions in this way is described in 2.3.) This is demonstrated by the following exchange.

FRIEND1: Last night, my cousin went bowling and then went to the ballet.
FRIEND2: That's an unusual combination, what kind of a person is your cousin?

The contradiction here is probably in the assumed SE-STATUS and/or the EDUCATION background of bowlers and ballets. While bowlers are generally fairly neutral characters, they do seem to be weakly stereotyped as lower middle-class, noncollegiate people. Ballet aficionados on the other hand are fairly strongly stereotyped as rich (or upper middle-class), well-educated people.

---

[9]This concept of an ERA is adopted from Kolodner [Kolodner 78]. The ERA time slices that we are using here are gross periods throughout an an entire lifetime. The organizing principle is that each unit typically indexes a strong person prototype of the sort described in [Cantor and Mischel 79].

The bowling role rule that we have been discussing is summarized as follows:

```
IF
   a person bowls,
THEN
   that person is likely to be:
     Lower Middle-class,
     A Dropout or High School Educated.
```

In the actual implementation of role features, there is a strength attached to each nominal value corresponding to how closely it fits into the MOP role stereotype. This strength is important when contradictions arise, as will be discussed in 2.3.

Before considering rules organized around other components, one final point about MOP roles should be made. As a character is successfully tied to a MOP role, experiential information about that character in that MOP situation may be accessed. This information can take the form of a particular interesting episode involving the character, or it can consist of modifications to the MOP role stereotype itself.

This is very important in the husband-wife conversation. As the wife hears the claim that her husband went bowling, she is reminded of his negative attitude to that particular activity. This attitude is a modification to the stereotypical bowler who bowls for entertainment.[10]

---

[10]Attitudes such as these are represented in MAGPIE with attitude primitives from Schank et. al. [Schank, Wilensky, Carbonell, Kolodner, and Hendler 78].

GOAL AND PLANNING RULES

One of the duties of the knowledge state tracker is to form an intentional explanation of events as they are described by the other conversant. The task is to to explain each event with a plan, each plan with a goal, and each goal with a supergoal or theme. Since this is fundamentally the same task that Wilensky [Wilensky 78] undertook in his story understanding program (PAM), many of the same planning rules will also be relevant in the MAGPIE system.

Referring to Figure 2-3, note that the bowling MOP network provides a declarative template embodying the following two PAM-like rules:

```
BOWLING-RECREATION RULE
   IF
      a person bowls,
   THEN
      that person is likely to have
       an ENTERTAINMENT goal that he
       is pursuing.

BOWLING-EXERCISE RULE
   IF
      a person bowls and
       is in an ERA later than MIDDLE-AGE,
   THEN
      that person is likely to have
       an EXERCISE goal that he
       is pursuing.
```

Entertainment and exercise goals are types of enjoyment and achievement goals respectively (from Schank and Abelson [Schank and Abelson 77]. Again, like all rules in the MAGPIE system, these goal/planning rules have strengths associated with them. Since bowling is a relatively mild activity physically, the strength of the first rule is usually greater than that of the second rule. However, strengths are

computed dynamically. The strength of the exercise rule is computed as a function of the ERA of the bowler. Old bowlers are likely to go bowling for exercise as well as for entertainment. The utility of rule strengths will be demonstrated in 2.3.

This MOP approach does offers some advantages over the PAM method. First of all, by using bidirectional semantic links (the set was adopted from Dyer and Lehnert [Dyer and Lehnert 80]), the converse rules need not be specified independently. The semantic link "intends" here specifies that the bowling plan (EV-BOWLING) is explained by the bowling goal, which in turn becomes entertainment or exercise (A-PHYSIQUE) as the knowledge structures overlap. Since the links are bidirectional, converse rules such as "IF a person has an exercise goal THEN that person might choose to bowl" need not be independently specified. Other semantic links such as ACHIEVED-BY and MOTIVATES facilitate tracking the status of goals. These are discussed at length in Dyer and Lehnert.

MOP events such as EV-BOWLING serve as both the plan and the event unit in this representation scheme. Plans are simply uninstantiated events in the template. Thus, the first step in explaining an event described by another conversant is to find the corresponding MOP event. This is equivalent in the Wilensky explanation scheme to finding a plan to explain an incoming event. The "intends" link in the MOP can then be traced back to find the goal that explains this plan.

Of course, one question that arises is: What happened to the "planboxes" employed by the PAM system? The answer is that the

information that was contained in planboxes is now embedded implicitly in the MOP events. MOP events are realized in one of two ways: by macro-CDs (described in Schank and Abelson [Schank and Abelson 77]) or by scripts. Planboxes originally served to specify the preconditions on which an event can take place. In the MOP scheme, these preconditions are specified by rules that operate on macro-CDs or scripts.

The precondition rules for macro-CDs are indexed by the primitive action predicates themselves. For example, the following rule is indexed by MTRANS MOP events:

```
MTRANS RULE
   IF
      a MOP event is specified by an MTRANS
       from person X to person Y,
   THEN
      person X must be near (PROX) person Y.
```

This incidentally captures the information contained in Wilensky's TELL planbox.

Script precondition rules provide more specific information. Consider for example the following rule which is used to infer that the husband was at a bowling alley:

```
LOCATION RULE
   IF
      a MOP event is specified by person X using
       a script that must occur at place Y,
   THEN
      person X must be at (PROX) place Y.
```

So far, the general strategy has been to:

1) Find the MOP event corresponding to the episode event described by the other conversant. (This is accomplished by MOP event rules which will be discussed next.)

2) Follow back the "intends" link to find the MOP goal
   to explain this MOP event.

But how are goals explained? In the Wilensky explanation scheme, goals are explained by either super-goals or themes. In this MOP application approach, a goal can be explained in two ways:

1) by finding a higher level goal in a more general MOP,
2) by recognizing that the goal is a "theme level" goal, and hence needs no further explanation.

The first of these is accomplished by traversing MOP-LINKs and looking for goal equivalencies. Referring to Figure 2-3, notice that the bowling goal (?G-BOWL) is set equivalent to the recreation goal (E-ENTERTAINMENT) when the MOP-LINK between the two knowledge structures has been activated. Thus the goal explanation task here reduces to the problem of knowing which MOP-LINKs to activate. MOP-LINKs have activation rules associated with them for accomplishing this. In the bowling example, the activation rules are precisely the BOWLING-RECREATION and BOWLING-EXERCISE rules presented on page 2.1. The recreation link is the default while the exercise link is only activated for elderly bowlers.[11]

The second goal explanation condition relies on the notion of a "theme level" goal. Goals are considered to at the theme level when they are sufficiently ubiquitous to not be considered in service to

---

[11] Of course, the one exception to this occurs when goals have been explicitly mentioned by the other conversant. In this case, all MOP-LINKs are traversed to attempt to make a fitting. Thus the bowling to exercise MOP-LINK is activated by sentences such as "I went bowling because I wanted to get some exercise."

higher level goals. Such goals are the basic elements of what Schank and Abelson [Schank and Abelson 77] refer to as themes. The E-ENTERTAINMENT and A-PHYSIQUE (achieve a good physique) goals fall into this category. These goals fit roughly into what Schank and Abelson might call the "have a happy life" and "maintain good health" life themes.

Applying the MOP goal and planning rules that have been presented here (along with a MOP event rule) will produce the intentional explanation for "I went bowling with the boys" shown in Figure 2-4.

```
E-ENTERTAINMENT
     *
    ?G-BOWL --+
              |
           intends
              |
          EV-BOWLING --+
                       |
                    instance
                       |
                    $BOWLING
             <bowler1:  husbands0
              bowler2:  friends0>
```

Figure 2-4: Explanation for "I went bowling with the boys."

In addition to the rules discussed so far, there is one more class of goal/planning rules: the goal-attitude consistency constraints. These rules verify that the attitudes of the characters in the episode are consistent with the goals that have been used to explain their actions. They are indexed by goal category. As an example, the following rule is accessed by the entertainment goal in the bowling explanation:

```
ENTERTAINMENT CONSTRAINT:
   IF
      an entertainment goal is used to explain
       an activity A by person X,
   THEN
      person X must LIKE activity A.
```

This constraint is violated by the husband's claim. As a result, further processing provides the wife with a new conversational goal. This will be described in 2.3.

The MOP explanation algorithm that the goal and planning rules embody is flowcharted in Figure 2-5. Step 2 is accomplished by applying MOP event rules, which will be explained later. Step 4 is accomplished by pattern matching incoming goals against MOP goal patterns.[12] While the hierarchy MOP-LINKs are traversed in step 5, the goals are instantiated and their attitude constraints are verified. Again, this only shows part of the process. There are other rules for tracking the status of goals, checking for goal interactions, and so on.

There is at least one significant theoretical difference between this approach and Wilensky's PAM model. Much of Wilensky's program involved the use of context independent rules. In this way, PAM applied a good deal of general planning knowledge to the task of understanding fairly specific episodes.

The MAGPIE knowledge state tracker on the other hand employs mostly

---

[12]Steps 4 and 5 are really integrated since any of the goals in the active MOP hierarchy could also match the input concept.

```
                1
                +-----------------------+
                | The incoming concept  |
                |      describes:       |
                +-----------------------+
                    |              |
                 AN EVENT        A GOAL
                    |              |
            +-------+              +-------+
            |                              |
      2     V                      4       V
      +-----------------+          +-----------------+
      |    Find and     |          |    Find the     |
      | instantiate the |          |  corresponding  |
      |  corresponding  |          |    MOP goal     |
      |    MOP event    |          +-----------------+
      +-----------------+                  |
            |                  +---------->|
      3     V                  |   5       V
      +-----------------+      |   +-----------------+
      | Follow back the |      |   |   Trace back    |
      | "intends" link  |------+   |   along goal    |
      | to get the goal |          | equivalencies   |
      |  explaining it  |          | in active MOP-  |
      +-----------------+          | LINKs until a   |
                                   | "theme" level   |
                                   | goal is found.  |
                                   +-----------------+
                                           |
                               +-----------+
                               |
                               V
                              exit
```

Figure 2-5: Goal/Planning Algorithm Used in Tracking at the Knowledge State Level

context dependent rules.[13] These rules are organized around specific goals and plans assigned to characters via MOP activation. Our claim here is that most planning situations are resolved by searching memory for specific plans organized around generalized episodes in the

[13] Context independent rules used primarily for coloring and instrumentality are used in the system, but are not discussed in this paper. The aim of such rules is to dynamically tie MOPs together that are not normally connected by MOP-LINKs.

planner's experience. Thus, a planner's first question is not "What general plan can I use here?" but rather "When have I been in a situation similar to this one?"

MOP EVENT RULES

MOP event rules are responsible for recognizing when the other conversant has described an action or state contained in the corresponding MOP. As has been discussed, MOP events are realized in one of two ways: by macro-CDs or by scripts. Thus the problem reduces to pattern matching incoming concepts against the macro-CD patterns in the MOP or invoking a script application algorithm.

Referring to Figure 2-3, observe that the only MOP event in M-BOWLING is EV-BOWLING. This event is realized by the bowling script ($BOWLING). The *MOP event rules for* bowling are implicit in this script. These rules are implemented by a script application algorithm similar to the one proposed by Cullingford [Cullingford 78]. It would be inappropriate to go into the details of this algorithm here. However, the following rule does suggest the kind of information contained in $BOWLING.

```
BOWLING SCRIPT
   IF
      a person X goes bowling,
   THEN
      person X is likely to:
      -choose a ball, then
      -approach the lane, then
      -release his ball, then
      ...
```

SETTING RULES

As shown in Figure 2-1, episodes are broken down into a series of

scene instances, corresponding the times and places at which events have taken place. For example, a bowling episode might include driving to the alley, contracting a lane, bowling some games, paying, and driving home. These scene instances take place on a road, at the counter of an alley, at a lane (or lane unit), at the counter, and on a road respectively. Setting rules track temporal and spatial constraints associated with MOP activities, and thus form the basis about which scene instances are organized.[14]

In addition to the MOP events that they organize, scene incidents include two setting slots: a time frame and a location.

The time frame is the general range of time in the day at which the episode takes place. Since time constraints (or expectations) for most activities are fairly vague, nominal values are used to fill the time frame slot. These values correspond to rough time units during the day like: MORNING (approx. 8:30 to noon), EARLY-EVENING (approx. 5:30 to 7:30), and LATE-NIGHT (approx. midnight to 7:00). As with role stereotypes, time stereotypes have associated strengths with each nominal value. The bowling time frame can be inferred by the following scene rule:

```
BOWLING TIME FRAME
   IF
      a person goes bowling at scene S,
   THEN
      the time of S is likely to be:
       EARLY-EVENING or EVENING-NIGHT.
```

---

[14]Schank has recently argued that contractual and personal settings are also useful for organizing MOP activities.

This rule was not needed in the husband-wife conversation since the wife knew explicitly when her husband was gone. (This will be discussed more later.) But in other circumstances, time frame rules become crucial. Consider, for example, the following exchange in which the time frame constraint is violated.

W1: Why were you out so late last night?
H1: I went golfing with the boys.

The other setting slot is the location. Many activities have constraints on where they take place. Bowling, for example, must take place in a bowling alley, at a particular lane. Hence two location tokens are created for the bowling episode: an alley token and an embedded lane token. The wife is likely to search for a specific referent for the alley token in her generalized knowledge about where her husband usually goes bowling. (Like attitudes, this knowledge is indexed by the role bindings in the MOP.) Or, she may explicitly ask her husband to fill the slot in by asking him which alley he went to.

Setting rules simply pair activities with their stereotyped times and locations. They in no way even begin to approach the complete knowledge needed for temporal and spatial reasoning. For a more complete discussion on this topic, refer to McDermott [McDermott 80].

Before summarizing the knowledge state tracking process, it is appropriate at this point to introduce one other MOP: M-WEEKDAY. This MOP is needed to deal with the initial problem presented in 1:3: What caused the wife to start up the conversation in the first place? Unlike M-BOWLING, this MOP consists almost entirely of indices to other MOPs.

Thus, the expectations organized by M-WEEKDAY serve more to activate other MOPs than they do to explain specific events directly.[15]

M-WEEKDAY

Most of the activities that people participate in are repeated over and over again on a cyclic basis. It is perhaps a sad fact that the lives of most people revolve around a fairly fixed routine of work and recreation. People know their own routines and sometimes the routines of those close to them very well. Expectations about what one will be doing at any given point during his routine can be very strong. Deviations from the routine are thus readily noticed. For this reason, the knowledge state tracker must access and apply rules relating to character's routine activities. These rules are organized around MOPS such as M-WEEKDAY.

MOPs typically organize memory indices around the activities that people participate in on a routine basis. The degree to which a person has a routine over the period of some cycle is related to the regularity at which activities in the cycle are repeated. People often have different routines for weekdays and weekend days. The detail in routines can vary greatly. Someone may have a very precise routine for his mornings, for example, and a very vague routine for his evenings. M-WEEKDAY organizes the expectations that the wife is likely to have

---

[15]In Schank's most recent theory, general MOPs such as M-WEEKDAY are likely to consist mostly of what he calls "placeholders" [Schank 81]. Such MOPs, which organize other MOPs rather than scenes, are called META-MOPs.

developed about her daily routine.

Before the husband-wife conversation takes place, the wife notices a deviation in the couple's normal evening activities. This deviation is due to the absence of her husband. Since he is not present, she is denied the pleasure (or perhaps feeling of security) that she usually derives from their personal interactions in the evening. Processing that begins with the recognition of this schedule deviation (in M-WEEKDAY) is what ultimately results in the wife opening the conversation with her husband.

Setting information provides the basis for indexing routine activities in M-WEEKDAY. This includes the rough time frame in which the activities occur and their general location. As an example, if it is early morning and the wife is at home, she is likely to expect to have a meal with her husband. A possible daily schedule (M-WEEKDAY) for the wife in the husband-wife conversation is shown in Figure 2-6 below.

The MOP shown in Figure 2-6 is intended to represent the wife's daily routine at a very gross level. Some activities, like perhaps PREPARATION, may really be much more rigid than what is shown here. Others, like EVENING, are likely to much more flexible.

One responsibility of the knowledge state tracker is to apply the rules that are implicit in the schedules of the conversants. This is what ultimately leads to the wife starting up the target conversation. The input to the MAGPIE program before the conversation begins is sketched below:

```
[SCENE
   TIME          EVENING-NIGHT          - it is late in the evening
   LOCATION      RESIDENCE0             - she is at home
   PARTICIPANTS  (WIFE0)          ]     - she is by herself
```

The MAGPIE program begins by finding the index to the expected activity during this time frame in M-WEEKDAY. In this case, M-RECREATION is activated. In building an episode for this activity, the program tries to verify the presence of the usual participants. It is at this point that she notices her husband is not home. Subsequent

M-WEEKDAY

UNIT OF ACTIVITY	LOCATION	TIME-FRAME	PARTICI-PANTS	ACTIVITY INDICES
PREPARATION	RESIDENCE	EARLY MORNING (7-8:30)	WIFE HUSBAND	*-----> M-CLEAN *-----> M-MEAL <breakfast>
WORK MORNING	OFFICE	MORNING (8:30-noon)	WIFE BOSS WORKERS	*-----> M-OFFICE
LUNCH	CAFETERIA	LUNCHTIME (noon-12:45)	WIFE BOSS WORKERS	*-----> M-MEAL <lunch>
WORK AFTERNOON	OFFICE	AFTERNOON (12:45-5:30)	WIFE BOSS WORKERS	*-----> M-OFFICE
DINNER	RESIDENCE	EARLY EVENING (5:30-7:30)	WIFE HUSBAND	*-----> M-MEAL <dinner>
RELAXATION EVENING	RESIDENCE	EVENING-NIGHT (7:30-12:00)	WIFE HUSBAND	*-----> M-RECREATION <TV, SEX, GAMES ..>
SLEEP	RESIDENCE	LATE-NIGHT (12:00-7)	WIFE HUSBAND	*-----> M-SLEEP

Figure 2-6: M-WEEKDAY: The wife's routine daily schedule

processing (of the sort described in 2.3) leads to the wife's overall goal of regaining lost dominance in the couple's relationship.

SUMMARY OF KNOWLEDGE STATE TRACKING

Perhaps the best way to summarize tracking at the knowledge state level is to relate the MOP rules that have just been discussed to the tracking algorithm. Recall from Figure 2-2 that each episode node has an associated expectation agenda. As episode nodes are traversed in an attempt to explain an incoming concept, the expectations on these agendas are executed.

The expectations on each episode node are inherited from the MOPs associated with that episode. It is these expectations that implement the MOP rules for roles, goals and planning, MOP events, and scenes (time and place). When a MOP is coupled with an episode node, its corresponding expectations are placed on that node's expectation agenda.

Figure 2-7 shows an example of a typical expectation agenda. The agenda control structure will repeatedly try all of the expectations at a given level until none of them "fire" (i.e. none of their tests are true). Then the agenda processor will move on to the next level, repeating the process. An episode's agenda has been fully executed when there are no more levels left to examine.

This section concludes with one final detailed example. Knowledge state tracking for "I went bowling with the boys" proceeds as follows:

1. The parser accesses the bowling MOP, M-BOWLING. A new EP node is created for this bowling episode. The following

Level	Expectations	
1	(MOP Role Rules)	restrictions, stereotypes
2	(MOP-LINK Rules)	expand to include new MOPs
3	(MOP Setting Rules)	time, location
4	(MOP Event Rules)	CD matcher, script applier
5	(MOP Goal Rules)	Goal matcher, "intends" tracer, "theme level" searcher, attitude consistency checker

Figure 2-7: EPISODE EXPECTATION AGENDA

expectations from M-BOWLING are placed on this node's agenda:

Level 1: Binding rules for filling the BOWLER roles,

Level 2: MOP-LINK rules for including M-RECREATION and M-SPORTING-ACTIVITIES, (These correspond to the rules shown on page 34.)

Level 3: Setting rules for filling in the time and location are added, (*Page 42 shows a time rule.*)

Level 4: A script applier monitoring the bowling script,

Level 5: Goal rules which try to explain MOP events and goals.

2. When the agenda created above is executed:

Level 1: The role bindings are taken directly from the parser representation, since the parser was able to resolve them.

Level 2: The episode is expanded to include M-RECREATION.

Level 3: A scene instance for an alley at night is created.

Level 4: EV-BOWLING ($BOWLING) is instantiated.

Level 5: An explanation for EV-BOWLING is sought. The result is shown in Figure 2-4 on page 38. However, the goal-attitude consistency constraint for ENTERTAINMENT goals (shown on page 38) fails. Further processing is discussed in 2.3.

2.2 Tracking at the Relationship Level

Tracking at the relationship level entails analyzing incoming statements for their effect on the relationship between the conversants. In the course of the analysis, certain processing events, specifically those associated with rule failures, can lead to the production of new relationship level conversational goals.

Goals at this level seek to change the existing relationship between the conversants. The change can be in intimacy, as in the case of two people trying to get better acquainted. Or it can be in dominance, as when one person tries to bully another. It can also be in positivity, as when former enemies try to "bury the hatchet." These three examples illustrate changes in the relationship along the dimensions used by [Schank and Abelson 77][16]:

- Intimate-distant
- Dominant-submissive
- Positive-negative

In addition to changing existing relationships, conversants can work towards establishing a new formal relationship. This is the case for example when a couple discusses the prospect of getting married. On the basis of these two possibilities, we adopt the following definition.

<u>A relationship level conversational goal either</u>:

<u>1. seeks to change the conversants' relationship along one</u>

---

[16] This dimensional analysis scheme was originally proposed by Joncas [Joncas 77] and adopted by Schank and Abelson for characterizing interpersonal relationships.

<u>of these dimensions, or</u>

2. <u>seeks to establish or terminate a formal relationship like marriage</u>.

Again, the goal of the relationship tracker is two-fold: to represent the content of statements at this level, and to monitor conversational goals. The control structure of the procedure is straightforward. An initial input to the program specifies the role that the machine is to play and the role of the other conversant.[17] As an example, we specify that the machine is to play WIFEO and we will play HUSBANDO in order to model dialogs like the one presented in the introduction. On this basis, the relationship tracker is initialized by accessing the appropriate relationship knowledge structures. Hence, the structure for marriage (R-MARRIAGE) and its associated structure IPT-LOVERS are accessed as soon as these two conversants are identified. (These will be discussed in detail later.)

WIFEO and HUSBANDO are tokens for specific people that MAGPIE knows about. This is an important point. A true model of a conversant must incorporate the specific memories, attitudes, and beliefs of an individual, since these are important factors in conversational behavior. WIFEO for example knows that her husband doesn't like to bowl, that he works during the day (he doesn't work evenings), and that

---

[17]The roles must be chosen from pairs for which knowledge structures have been defined, as will become evident.

he can't always be trusted. Thus, MAGPIE always models a specific individual. To this end, the relationship tracker initially accesses a third knowledge structure, R-MARRIAGE0, which incorporates specific information about the marriage of WIFE0 and HUSBAND0.[18]

As the appropriate knowledge structures are activated, an agenda of "requests" is associated with the instantiated node (in this case, R-MARRIAGE0). In the actual implementation, these requests procedurally interpret the information encoded declaratively in the knowledge structures. However it is useful to think of the agenda requests as procedural rules that reflect the content of the knowledge structures. This overall configuration is sketched in Figure 2-8 below.

```
+-------------+  +-------------+
| R-MARRAGE   |==| IPT-LOVERS  |
+---------*---+  +-*-----------+
          *        *
       instantiation
          *        *
     +-----------------+
     |    MARRIAGE0    |------+
     | (their specific |      |
     |    marriage)    |   MARRIAGE0
     +-----------------+     RULE
                            AGENDA
```

Figure 2-8: MARRIAGE relationship knowledge structure scheme

Agenda requests are used in two ways: to specify constraints and to specify expectations. Constraints describe necessary antecedent-consequent conditions while expectations are traditional

---

[18]Specific information is encoded in terms of its deviation from the prototype. The only relevant deviation in R-MARRIAGE0, is the wife's somewhat diminished trust toward her husband. This is actually used by the truth and trust tracker in detecting his lie in statement H1.

test-action productions. The form of an agenda request is similar to that of a parsing request described in [Riesbeck and Schank 76]. However they have been extended somewhat to deal with request failures. A failure occurs in one of two cases: if an antecedent is true but its consequent isn't, or if an expectation is "strong" but its test is not satisfied. Processing in these cases resumes with the execution of the ELSE clause. Two typical agenda requests are shown below.

SEX CONSTRAINT (for husband)

```
+------------------------------------+
| TYPE:  CONSTRAINT                  |
| ANTE:  [AND                        |
|          (R-MARRIAGE HUSB #H WIFE #W)|
|          ($SEX MAN #H WOMAN #P1)]  |
| CONS:  (SAME TOKEN1 #W TOKEN2 #P1) |
| ELSE:  (BUILD <infidelity CTP>)    |
+------------------------------------+
```

COMPANIONSHIP EXPECTATION

```
+--------------------------------------+
| TYPE:  EXPECTATION                   |
| TEST:  [AND                          |
|          (R-MARRIAGE HUSB #H WIFE #W) |
|          ($HOME-ACTS HUSB #H WIFE #W)]|
| ACT:   (BUILD <companionship goal>)  |
| STRTH: < f(#H,#W)=schedule(#H,#W) >  |
| ELSE:  (CHECK-GSF HUSB #H WIFE #W)   |
+--------------------------------------+
```

These two requests illustrate a constraint and an expectation respectively. The first request specifies that husbands should have sex with their wives only. A violation of this constraint leads to the formulation of a relationship infidelity CTP. (CTPs are described in section 2.3.). The second request specifies the expectation that married people get together at home periodically to enjoy each other's company. The strength of this expectation is a function of the couple's

routine schedule, described in the previous section. If the expectation is strong and it fails, a check is made to see if one member of the relationship is not fulfilling his (her) responsibility to provide companionship.

The tracking algorithm is quite simple: execute the rule agenda associated with the relationship between the conversants.[19] Our thesis here is this: The dimensions signified in the knowledge structures represent the "stable" condition of the relationship. It is stable in the sense that if no rules are violated, both members of the relationship are content. However, a violated rule signifies a possible shift along one or more of the dimensions. This in turn elicits a relationship level goal in any member(s) who is left discontented by the shift. Thus, if someone feels he is losing dominance, he will probably try to regain it. This usually comes to the surface as an accusation directed against the offending party. We shall illustrate this with some examples in the section 3.

The key to all of this of course lies in the rules that reflect the knowledge structures. So our next step in explicating the relationship tracker will be to examine the content of RELATION and INTERPERSONAL THEME knowledge structures.

---

[19]This is not to say that couples do not have more than one relationship. Sometimes, for example, married couples are also fellow workers, business partners, and so on. The complete algorithm executes all of the relationship agendas.

Schank and Abelson [Schank and Abelson 77] propose relationship knowledge structures to organize rules about how people in relationships typically deal with one another in various situations. Some examples of relationships they discussed include FRIENDS, LOVERS, and BOSS/EMPLOYEE. The rules associated with these relationships dealt primarily with goal interactions.

Relationships such as these can be divided into two categories:

1. those that are formally defined liked MARRIAGE, ROOMMATES, and PROFESSOR/STUDENT,

2. those that are informally defined like LOVERS, FRIENDS, and ADMIRER/ADMIREE.

The first category of relationships will be referred to as RELATIONs while the second category will be referred to as INTERPERSONAL THEMEs (the original Schank and Abelson term). Relations have associated with them formal boundaries (as to when they begin and end) and formal, often contractual, obligations. Typically, an important aspect of a relation is the attitude(s) that the people in the relation hold toward each other. For example, a crucial aspect of marriage is that the partners love one another. Interpersonal themes, like LOVERs, organize rules associated with the attitudes implicit in formal relations. Thus, relationship tracking relies on applying information both from the formal RELATION between the conversants, and the attitude(s) between the conversants implicit in the corresponding INTERPERSONAL THEME(s). So requests placed on the rule agenda

associated with the conversants' relationship (refer to Figure 2-8) are inherited both from a RELATION and an INTERPERSONAL THEME knowledge structure. (in this case, R-MARRIAGE and IPT-LOVERs). Relations and interpersonal themes are represented as interconnecting structures, each of which organizes rules about goal interactions, obligations, and attitudes. These structures consist of the following components:

- Roles: the people involved in the relationship (NOTE: Role themes from Schank and Abelson focus on the relationship from a single perspective. As an example, there are some rules that can be associated with HUSBAND that are not associated with WIFE, and vice versa. For purposes here, roles are simply variables that get bound to WIFE0 and HUSBAND0.)

- Goal Subsumptions: the goals that are normally subsumed by the relationship and indices to the activities that subsume them (The notion of goal subsumption via a relationship is due to Wilensky, [Wilensky 78]. These indices are pointers to MOPs.

- Attitudes: attitudes that the roles have toward each other (Refer to Schank, et. al. [Schank, Wilensky, Carbonell, Kolodner, and Hendler 78], on the representation of attitudes.) and the foundation linkage from relations to interpersonal themes,

- Co-participation Restrictions: goals that are supposed to be pursued jointly, activities that are supposed to be

participated in together,

- Dimensional Analysis: scale values for Positive/Negative, Intimate/Distant, and Dominant/Submissive dimensions on the relationship.

The interaction rules of the relationship (which are realized by the agenda requests) are organized around these components. This is best illustrated by an example. A representation of the husband/wife relationship is shown in Figure 2-9 below.

Now consider some of the rules that these components organize.

GOAL SUBSUMPTION RULES

Goal subsumption rules address the cyclic goals that are subsumed by the relationship. Some of them also incorporate contractual responsibilities. A contractual responsibility specifies an activity that must be performed with the relationship partner only. Violation of a contractual responsibility is grounds for terminating the relationship. The S-SEX subsumption declaratively represents the following rule:[20]

```
S-SEX SUBSUMPTION RULE
IF
   person W and person H are married,
THEN
   W and H satisfy each other's need for sex, and
   W and H do not have sex with other partners.
```

ATTITUDE RULES

---

[20]The SEX CONSTRAINT mentioned previously is one of the agenda requests that realize this rule.

```
              R-MARRIAGE
  +--------------------------------------+
  |                                      |
* * * ROLES:  WIFE, HUSBAND              |
* |                                      |
* |        Goal Subsumptions:            |
* |           S-SEX  --------------------> $SEX
* |           S-COMPANIONSHIP -----------> <recreation>
* |                                      |
* |        Attitudes:                    |
* |           TRUST ---------------------> IPT-FRIENDS
* |           LOVE ----------------------+
* |                                      | |
* +--------------------------------------+ |
*                                          |
*                                          |
*                 +------------------------+
*                 |
*                 V
*
*             IPT-LOVERS
* +--------------------------------------+
* * * ROLES:  LOVER-A, LOVER-B           |
  |                                      |
  |        Co-participation              |
  |          Restrictions:               |
  |          S-SEX                       |
  |          ENTERTAINMENT Goals         |
  |                                      |
  |        Positive/Negative: 10         |
  |        Intimate/Distant: 10          |
  |        Dominant/Submissive: 0        |
  |                                      |
  +--------------------------------------+
```

Figure 2-9: HUSBAND/WIFE RELATIONSHIP

The attitude rules in relationships are indexed by the attitude primitives that represent them. [Schank, Wilensky, Carbonell, Kolodner, and Hendler 78] The following rule, for example, is indexed by the TRUST attitude that married people hold for each other.

```
TRUTH RULE
IF
   person W and person H are married,
THEN
   person W and person H tell the truth to each other.
```

CO-PARTICIPATION RULES

These rules specify broad classes of goals that people in relationships like to pursue together. These are not necessarily goals that are subsumed by the relationship. Rather these are goals that are satisfied by activities that both partners typically attend. As an example, married people often go to the movies together. Or more generally:

```
ENJOYMENT RULE
IF
   person W and person H are lovers,
THEN
   person W and person H usually pursue enjoyment
    goals together.
```

A violation of a co-participation rule is interpreted as an inconsistency in the attitude organizing the interpersonal theme. So, for example, when the husband claims that he enjoys bowling with people other than his wife, she takes it to be an expression of his lack of love for her.

DIMENSIONAL ANALYSIS RULES

The dimensions of the relationship organize rules for dealing with goal interaction situations. As an example, since marriage is high along the POSITIVITY dimension, we would expect married people to help each other achieve goals. This is expressed by the following rule:

```
AGENCY RULE
IF
   person W and person H are in a positive relationship
    and W expresses an agency goal to H,
THEN
   H will assist W.
```

We have already seen how these dimensions are used to characterize

conversational goals at the relationship level. Recall that the task at hand is both to build representations and to track conversational goals. Representations at this level take two forms: theme goals and conversational trace points. Theme goals are created by subsumption and co-participation rules which address the consistency of behavior with the relationship. Suppose for example that a husband tells his wife "I want to go to the movies with you tomorrow night." At the knowledge state level, this is parsed as an expression of an entertainment seeking goal. At the relationship level, a companionship goal is instantiated to represent the husband's desire to remain intimate with his wife.

Theme goals such as this are created when relationship rules succeed. The most interesting case however is when the rules do not succeed. Such situations suggest a possible shift along one or more of the relationship dimensions. These potential shifts are represented by conversational trace points (CTPs). CTPs will be described in the next section as a mechanism by which new conversational goals are acquired.

2.3 Conversational Trace Points: A Source of Purpose in Conversation

In 1.3, the notion of conversational purpose was introduced. More specifically, in addressing the target conversation, we asked: "What caused the wife to start the conversation in the first place?" The general problem here is to identify some sources of purpose in conversation. What processing events give rise to conversational goals?

Before proposing an answer to this question, some generalizations about conversational goals should be pointed out. First of all, while

conversants often act in accordance with an overall purpose, this does not limit the scope of their conversational intentions. Individual statements reflect both an overall conversational purpose and more localized desires. Consider, for example, the wife's response to her husband's claim tc have been bowling:

W1: I thought you hated bowling.

The wife's overall goal in the conversation is to regain relationship dominance. Quite simply, she feels that her husband has shirked his responsibility and she is trying to regain dominance by getting him to admit it. Notice here that she is adopting a more localized goal as well. Specifically, she is trying to get her husband to confess to a lie. She may also be expressing anger and trying to find out where he really was.

This example illustrates another aspect of conversational purpose as well. New conversational goals arise dynamically as conversations proceed. The wife adopted this new goal(s) in response to her husband's lying. Goals such as this come and go throughout conversations.

The example also illustrates a conversant's capacity to deal with several goals simultaneously. In this single statement, the wife is pursuing a dominance goal, a goal to find out where he was, a goal to get him to admit to lying, and a need to express her anger. Another illustration of this is the wife's opening line:

W0: Why were you out so late last night?

This single question accuses her husband of doing something wrong,

expresses anger, and asks where he was. It illustrates that many goals exist simultaneously in conversation and individual statements can pursue many of them.

One final observation is that conversational goals address communication at a variety of levels. Not all goals are limited to information flow at the knowledge state level. We have also seen, for example, goals relating to relationship, truth and trust, and emotional information. In section 3, a taxonomy of conversational goals intended to organize response strategies will be presented. But for now, we will address the issue of determining how these goals come into existence.

To summarize, a conversational goal source must:

1. Generate local as well as overall goals,
2. Generate goals during the conversation as well as before it,
3. Generate multiple goals simultaneously,
4. Generate goals addressing information at many levels, not just at the knowledge state level.

The sources we propose here are the very tracking processes that have been discussed up to this point. Conversational goals arise from tracking information flow at the various levels of communication. This fits in well with the criteria listed above. Some information trackers are consistently active throughout the conversation (like the relationship tracker) while others are most active in local bursts (like the KS tracker, which is most active at the beginning). This is consistent with the first criterion. Since tracking goes on throughout the conversation, the second criterion is also met. And since tracking

goes at multiple levels, the third and forth criteria are met as well.

What processing events during tracking give rise to conversational goals? One answer to this is the processing of rule and expectation failures. The mediating mechanism that we propose for this is the conversational trace point.

A conversational trace point (CTP) marks an interesting aspect of the incoming statement with respect to the conversational level that is being tracked. It is, in a sense, a focus marker on something that has been encountered during the understanding process. In this way, a CTP is similar to the processing trace elements for story understanding discussed in Lehnert [Lehnert 79]. Interestingness here is purely a function of the strength of the rule or expectation that has been violated. As strong violations occur, the appropriate CTPs are generated. These CTPs in turn specify the generation of new conversational goals.

To see how this works, consider again the following line from the target conversation:

H1: I went bowling with the boys.

The last few sections have shown how this statement is tracked at the knowledge state and relationship levels. In addition to these, truth and trust (T&T) tracking is also crucial here. Without going into details, the T&T tracker is operating on a rule that expects people in positive relationships to tell the truth to each other. However, it is also scrutinizing answers carefully since the couple is in an argument.

Ultimately, it interprets strong knowledge state inconsistencies as lies under these circumstances.

To begin the analysis, recall what happens at the knowledge state level. The processing is summarized by the agenda execution listed on page 48. Notice that the role binding and event explanation expectations all succeed. The only rule that fails is a goal-attitude constraint (for entertainment/pleasure, discussed on page 38 and repeated below.)

```
ENTERTAINMENT CONSTRAINT:
   IF
      an entertainment goal is used to explain
       an activity A by person X,
   THEN
      person X must LIKE activity A.
```

The failure of this rule gives rise to a plan inconsistency (KS-PI) CTP at the knowledge state level. Plan inconsistency CTPs arise when the knowledge state tracker finds a planning non sequitur during the explanation process. (In actual implementation, MAGPIE generates CTPs by executing the ELSE portion of agenda rules when the STRENGTH of the rule is sufficiently high. STRENGTH and ELSE clauses are discussed on page 24.) As part of the dialog representation, an instantiation is made for this type of CTP, and a set of goal production rules is made active. (Each type of CTP indexes a set of such rules.) Of these, the following rule associated with plan inconsistency CTPs leads to the generation of a new conversational goal at the knowledge state level.

IF
   the plan inconsistency is due to
    a goal-attitude constraint failure,
THEN
   generate the conversational goal:
     KS-SEEK <goal-attitude resolution>.

KS-SEEK is a conversational goal to obtain information from the other conversant. The parameter here (goal-attitude resolution) specifies that the inconsistency to be explained is from an assumed goal and an assumed attitude. In the absence of all other goals, the KS-SEEK strategy rules (discussed in section 3) would apply to generate a response like the following:

W1-a: Do you like bowling now?
W1-b: Didn't you want to have a good time?
W1-c: I thought you hated bowling.

Notice that the third response is the one that actually appears in the target conversation. In another context, the wife could be expressing confusion, not making an accusation.

The T&T tracker which has not been discussed in detail attributes the attitude inconsistency to lying. The factors that lead to this interpretation include the argument situation, the severity of the inconsistency, and the wife's lack of complete trust toward her husband.

Recall from 2.2 that R-MARRIAGE has an attitude rule based on the premise that married couples should trust each other. This rule (shown on page 57 and repeated below) simply specifies that spouses should tell the truth to each other. While processing at the relationship level, this trust rule is violated. This causes an attitude inconsistency (REL-AI) CTP to be generated. Attitude inconsistency CTPs correspond to

cases in which one partner has exhibited behavior contrary to an attitude implicit in the relationship. In this case, the husband has violated TRUST.

```
TRUTH RULE
IF
   person W and person H are married,
THEN
   person W and person H tell the truth to each other.
```

REL-AIs are considered to be threatening to the relationship. Generally speaking, they are interpreted as unfulfilled obligations, like the husband's absence the night before. By blatantly lying to her, the wife feels that her husband is failing to show her "respect" in the relationship. Thus the following REL-FA rule leads to the generation of another conversational goal, this time at the relationship level.

```
IF
   the foundation-attack is a
    violation of the TRUST attitude,
THEN
   generate the conversational goal:
     D-REL <dominance, ...>.
```

When this goal is pursued (as discussed in section 3), the following type of responses can be generated:

W1-a: I thought you hated bowling.
W1-b: You liar, you hate bowling.
W1-c: You shouldn't lie like that to your wife.

This example illustrated how CTPs are generated during tracking as a result of expectation and rule failures. Some rules associated with CTPs for generating conversational goals have also been presented. While this is probably not the only mechanism by which goals can be generated, it does seem to be adequate for generating many of the goals in the target husband-wife conversation. Some common CTPs that arise

from expectation (or rule) failures while processing at the knowledge state and relationship levels are shown below.

Knowledge State Level:

-Expectation Failure-	-CTP-	
Unfilled Slot(s)	KS-IU:	Incomplete Understanding
Role Stereotype Deviation	KS-NB:	Novel Binding
Event didn't occur	KS-NE:	Non-event
Goal-attitude inconsistency or contrary goal	KS-PI:	Plan Inconsistency

Relationship Level:

-Rule Failure-	-CTP-	
Role Stereotype Deviation	REL-NB:	Novel Binding
Goal Subsumption Failure	REL-UO:	Unfulfilled Obligation
Attitude Inconsistency	REL-AI:	Foundation Attack

Each of the CTPs listed above is generated by the failure of a specific expectation or rule. For example, KS-NE (Non-event) is generated when an expected event is explicitly stated to not have occurred, as in:

FAN1: I went to the baseball game yesterday but didn't see a thing.

The goal that is generated is to find out why the fan couldn't see the game. Some possible responses are shown below. Responses b and c are generated by checking for precondition failures.

GOAL: KS-SEEK -- find out why FAN1 didn't see the game.

FAN2-a: Why not?
FAN2-b: Did you have bad seats?
FAN2-c: Did people keep getting in your way?

Before summarizing CTPs, one more example from the target conversation will be discussed briefly.

At the beginning of this section, I reiterated the original problem proposed in 1.3: What overall purpose did the wife have in starting the

conversation in the first place? Recall from page on 45 that the initial input to the MAGPIE program is that the wife has found herself home alone during the late evening. From this initial state, the wife generates two primary goals: to regain relationship dominance and to discover the whereabouts of her husband the night before.

Processing begins at the knowledge state level by applying M-WEEKDAY shown in Figure 2-6 on page 45. Immediately an expectation fails since the husband is not home. This causes two things to happen: the wife generates an M-RECREATION (this is the usual activity) episode for herself with a failed entertainment goal and she generates an unknown (empty) episode for her husband. After that, processing proceeds as usual by considering the expectations associated with these episodes.

An incomplete-understanding CTP (KS-IU) is generated by the husband episode since it is completely empty. (This is from an initialization expectation placed on episodes before they are linked to knowledge structures.) This CTP in turn causes a KS-SEEK conversational goal to be generated in order to find something out about the blank episode. Had this goal been pursued by itself, the conversation may have started with:

W0: What were you doing last night?

An unfulfilled obligation CTP (REL-IU) is generated at the relationship level since the wife's usually subsumed companionship goal has been blocked by the absence of her husband. This CTP causes a

relationship dominance goal to be generated in keeping with the following rule:

IF
  a relationship partner fails to fulfill an obligation,
THEN
  generate the conversational goal:
    D-REL <dominance> to regain lost dominance.

This D-REL (delta-Relationship) goal reflects the wife's general purpose in starting the conversation. She does not want her husband to get away with shirking his responsibilities in their relationship. Her strategy (which will be discussed in section 3) is to accuse him of improper behavior. This is implicitly pursued in her opening statement:

WO: Why were you out so late last night?

Again, this relationship goal and the previous knowledge state goal were both generated via expectation (or rule) failures.

To summarize, the conversational trace point has been introduced as a mechanism by which conversational goals can be generated. While this is certainly not the only processing event that can give rise to these goals, it does seem to reflect one important generalization about the conversation process. The important point here is that CTPs mark deviations that arise while understanding another conversant. At the knowledge state level, CTPs often mark failure[illegible] script application or explanation formation. At the relationsh[illegible] CTPs signify possible shifts in the conversants' relationship along various dimensions (positivity, intimacy, dominance). Such deviations can intrigue, anger, threaten, and generally affect a conversant in many ways. But the one

thing that deviations all have in common is that they motivate a conversant to respond to them. It is on this basis that new conversational goals can be acquired.

3. Pursuing Conversational Goals

Once a set of conversational goals has been formulated, it is the speaker's task to create an utterance which will satisfy these goals. Ideally, all goals present at a particular time can be satisfied or partially satisfied by a single utterance. For example, the goal of opening a lock, finding out what the combination is, and telling someone why you don't know the combination can all be achieved in the single utterance, "It's been a year since I tried to open this lock," assuming, of course, that the other person is likely to know the combination. In this section, we will describe how MAGPIE pieces together such utterances. We will assume throughout that the construction of each statement involves an attempt to satisfy all active conversational goals.

3.1 Stages in the Planning Algorithm

Combining goals into a single statement in order to achieve an objective is a planning process. The planning algorithm that we propose relies on the following four types of knowledge:

1. plans for the achievement of each goal,
2. strategies for putting a plan into action,
3. knowledge of the effects of an action on the other person,
4. knowledge of the combined effects of a set of actions on the other person.

The MAGPIE planning algorithm for building statements is really a systematic application of each of these types of knowledge. Perhaps the clearest way to present the algorithm is by using an example. We will

consider first a case in which the speaker has a single goal, to find something out (KS-SEEK). Reference to Figure 3-1 might be helpful in following the logic through the next few paragraphs.

```
Goal           Plans
----        +-------------+
KS-SEEK --->| 1) REF-BOOK |              Realizations of ASK
            | 2) SEARCH   |   +----------------------------------------+
            | 3) ASK ---------->| 1) STATE X, missing knowledge of self.   |
            +-------------+   | 2) STATE relevant knowledge of other.   |
                              | 3) REQUEST relevant knowledge of other. |
                           +---| 4) QUESTION X, missing knowledge of self.|
                           |  +----------------------------------------+
                           |
     Effects of QUESTION   |
    (State of the other)   V
 +---------------------------------------+
 | KS:  Other knows Speaker doesn't know X.|
 |      Other knows X.                    |
 |      Other has KS-TRANS goal.          |
 | EM:  (Other is angry.)                 |
 |      (Speaker is incompetent.)         |
 |      (Other has EX-EMOTION goal.)      |
 | REL: (D-REL Speaker loses status.)     |
 +---------------------------------------+
```

Figure 3-1: The KS-SEEK goal with 3 associated plans, realizations of the ASK plan, and effects of the QUESTION realization. S is the speaker, L is the listener, X is the missing knowledge.

The first task once a goal arises is to formulate a plan for its achievement. Traditionally, planning has involved physical actions such as "MOVE object A to location B," but there is no reason why "conversational actions" can not also be planned. (This view is not new, see [Allen and Perrault 80]).

There are various plans for achievement of KS-SEEK; looking up the desired information in a reference book, searching for an example of the desired object to examine, or getting another person to tell you about it are a few examples. These options are diagrammed in the second

column of Figure 3-1. Currently, the distance between a goal and a plan to achieve it is traversed by discrimination nets in which the decision nodes are strategy rules. One possible set of discriminations to go from the KS-SEEK goal to its associated plans is outlined in Figure 3-2. In the case of the speaker in this situation, she desires information about his activities, so he is the best source. Since he is there, the ASK plan is chosen.

```
KS-SEEK(X) ---> PROXIMATE AVAILABLE SOURCE
                      OBJECT -----÷> BOOK  ----------> P-REF-LOOKUP
                                     SEEK÷OBJECT ----> P-EXAMINE
                      PERSON  ----÷> KNOWS(X) -------> ASK
                                     NEG(KNOWS(X) ---> D-AGENCY
                NO PROXIMATE AVAILABLE SOURCE ------> D-PROX, SEARCH
```

Figure 3-2: Possible discriminations to arrive at a plan from the KS-SEEK goal.

Once a plan has been chosen, there are various strategies available for it´s realization. Continuing with our ASK example, there are many ways to elicit information from another person. Some possible realizations of the ASK plan are to tell the other conversant what the planner doesn´t know: "You know, I can´t figure out how this circuit works," compliment them on their knowledge: "You are the only person around who knows anything about circuits," request the information indirectly: "Do you know how a circuit like this works?". or question them directly: "How does this circuit work?", Realization strategies are virtually endless, and will vary from person to person and situation to situation. We also utilize a discrimination net to go from plans

through realization rules to an utterance.[21]

In the case of the ASK plan, if there are no extenuating circumstances, the most straightforward realization strategy, QUESTION, is chosen. Extenuating circumstances in this case would include interpersonal factors such as dominance. If the person with the desired information is of higher status than the questioner, for example, an indirect request might be appropriate.

The problem of actualizing questions in a natural language (from CD) is a generation issue that has been discussed extensively elsewhere [Lehnert 78]. Briefly, in Lehnert's scheme, questions are categorized according to the main concept which is being queried (i.e. MOTIVATIONAL, CAUSAL ANTECEDENT, VERIFICATION, etc.), and then slots are filled to help identify the question concept to the listener. For example a "reason question" is put together by adding "Why" to the front of a description of the event or state being asked about, a verification question is always of the form "Did X?" or "Is X?", etc.

Once the utterance has been formulated, it seems that the task is complete. But one important step remains, the effects of the chosen strategy must be recorded in memory. By keeping track of the effects of utterances a conversant knows the state of the other person and can keep

---

[21]The MAGPIE system currently produces responses in conceptual dependency (CD) notation. Although there is a working CD to English generator [McGuire 80], we have not yet realized a connection between this program and MAGPIE.

track of how the conversation is moving. The effects, which we will say are kept in a "table of effects", are monitored at all of the conversational levels discussed in section 2. We propose the table of effects as a data structure for the on-line tracking of conversational plans.[22] Thus, an utterance is checked for its impact on the listener on the knowledge state level, the emotions level, the relationship level, etc.

Effects entered in the table of effects are both effects on the state of the other person and effects on the states of oneself revealed to the other person. Thus, in saying "You know a lot about how circuits work, don't you?", a conversant both creates a pleased or competent feeling in the listener (on the emotional level) and reveals to the listener that the conversant doesn't know something about a circuit (on the knowledge state level). The former is knowledge, in the speakers memory, about the state of the listener as a result of what was said. The latter is knowledge, in the speaker's memory, about what the listener now knows about the speaker. These "who knows what about who" contortions are familiar to researchers in conversation [Allen and Perrault 80], and are necessary to explain how speakers and listeners maintain shared concepts as reflected in unusual anaphoric statements, "Like what I was saying," and the careful use of appropriate levels of description which do not bombard the listener with things already known.

---

[22]Tracking the effects of plans using this type of technique was proposed by [Sacerdoti 74].

In conversation planning, the conversant can never be too sure of the effects of an utterance. We will distinguish between two types of utterance effects: necessary effects and side effects. Necessary effects are very probable expectations about the state of the other person after an utterance is made. For example, a statement of fact can be expected necessarily to tell the other person that the speaker knows the fact and introduce the fact into the listener's conversational memory. Both of these effects are recorded as necessary effects. Necessary effects are indexed directly with realization strategies. When a strategy is adopted, the necessary effects are always added immediately to the table effects.

Under certain circumstances a statement may also have side effects as well. For example, a statement of fact that a speaker knows might be offensive may make the listener angry. Side effects must be watched carefully, both in order to avoid undesired consequences of a statement and to create desired states indirectly. Side effects must always be computed and will vary considerably from situation to situation. They are thus not indexed directly by realization strategies (it makes no sense to index Anger with the QUESTION strategy, for example, although it could be a side effect). Generally, side effects arise from the CTPs which gave rise to the motivating conversational goals in the first place.

In our example in Figure 3-1, the QUESTION realization is processed first on the knowledge state level. It is determined that the listener

will learn that the speaker doesn't piece of information queried and that the listener in fact does. In normal situations, the listener can be expected to reply to the question with a transfer of the fact back to the speaker. In other words, asking a question is likely to induce a knowledge transfer goal (KS-TRANS) in the listener. Thus expected conversational goals at various levels are also kept in the table of effects. The expected conversational goals present in the table of effects when a reply is made are used in helping to comprehend the reply.

At the EMOTIONS level we have considered a possible side effect of the question, namely that the listener could become angry. This type of effect is not a necessary consequence of asking a question, but arises because an interpersonal situation about which the speaker knows. Perhaps the speaker asks a lot of questions of this person, or perhaps the speaker asked the same question shortly before. Whatever the reason, it gives rise to an expectation that the listener may become angry and formulate a goal to express the anger.

Now all of the effects listed in the table of effects could turn out to be wrong, in particular the goals might be misjudged. But it seems that human conversants must face this possible confusion in natural dialog. Because a conversant can be sure of nothing during discourse, the table of effects must be referenced constantly to monitor the fate of expectations. If contradictory expectations arise in the effects table, then somehow the dialog has run astray and the effects

must be reconciled.

Other conversational planners have taken the effects of planning operations for granted. For example, in the query system of Allen & Perrault, which models a customer seeking assistance at a train station, the automatic cooperation of the information booth attendant must be assumed in order to plan and execute requests. Such a strategy would not work at a real train station. Planning can never reach too far, and effects are never certain.

3.2 Pursuing Multiple Goals

Most statements in a natural dialog serve more than a single goal. Instead, they are multiply-motivated. As an example, "Why were you out so late last night?" is not just a simple question about the husband's motivations. It also expresses a certain amount of displeasure and implies that a justification is in order.

We saw in section 2 that conversational goals are generated on many levels. Thus, the input to the MAGPIE planner is a set of active goals, not just a single goal. It is presumed that a speaker will attempt to satisfy as many goals as possible in a single utterance. We thus have to add to the general algorithm outlined in Figure 3-1 a capacity to combine conversational plans. This is accomplished by choosing plan realizations with overlapping effects.

When each CTP is activated, the goal it gives rise to is is placed into a queue. The queue of conversational goals is assembled along with other relevant information into a single "dialog profile." At any given

point in a conversation, the dialog profile organizes the active conversational goals and plans. This data structure serves as the interface between the tracking algorithms discussed in section 2 and the planner.

The goals in the queue are ordered with respect to their relative importance. As yet, we have not settled on a single mechanism for measuring the relative importance of conversational goals. Empirically, we have found that shifting the order in the goal queue leads to the generation of different, but still plausible responses.

The planner processes each goal in the order it appears in the queue. The first goal in the queue gives rise to the first utterance prototype. In general, the final statement will be very much like this original formulation. All other realizations of goals will actually be modifications to this initial prototype. They are not trivial modifications, of course, since each one adds a new meaning to the utterance.

Let's consider the wife's first statement, "Why were you out so late last night?," as an example of the multiple goal planning process. Figure 3-3 shows the conversational goals, KS-SEEK, EX-EMOTION, and D-REL(dominance), as they are processed in turn. Note that the planning phase of the first, knowledge seeking goal is the same as that discussed in section 3.1, with the additional specification that the realization of the ASK plan be a question of type MOTIVATION.

The effects of the QUESTION are shown in the initial table of

effects. (Side effects are parenthesized.)

```
1) KS-SEEK: Husband's location last night.
   |
   +- plan -> ASK: Reason husband was out late last night.
               |
               +- realization -> WHY-QUESTION: "Why were you out late <-+
                       effects|             last night?"                |
                              V                                         |
      +-----------------------------------------------+                 |
      | KS:  Wife knows Husband was out late.         |                 |
      |      Wife wants an explanation of whereabouts. |                |
      |      (Wife wants to know whereabouts.)        |                 |
      | EM:  (Husband is guilty.)                     |                 |
      |      (Wife is angry.)                         |                 |
      | REL: (D+REL, Wife gains dominance.)           |                 |
      +-----------------------------------------------+                 |
                                                                 modify |
2) EX-EMOTION:  Anger.                                                  |
   |                                                                    |
   +- plan -> EMPH: Source of anger, schedule violation.                |
               |                                                        |
               +- realization -> EMPH Time: "Why were you out so late --+
                              |           last night?"                  ^
                      effects |                                         |
                              v                                         |
      +-----------------------------------------------------+           |
      | KS:  Wife knows the episode was a schedule violation. |         |
      |      Husband knows he did something wrong.          |           |
      | EM:  Wife is angry.                                 |           |
      |      Husband is guilty.                             |           |
      | REL: D+REL, increase in dominance for the wife.     |           |
      +-----------------------------------------------------+           |
                                                                 modify |
3) D+REL: Wife wants some dominance back in the relationship.           |
   |                                                                    |
   +- plan -> ACCUSE: Husband of schedule violation.                    |
               |                                                        |
               +- realization --> ACCUSATION: ("You were out so late ---+
                        effects|            last night, why?")
                               V
      +-----------------------------------------------+
      |*KS:  Wife knows Husband was out late.         |
      |*EM:  Husband is guilty.                       |
      |      (Wife is angry.)                         |
      |*REL: D+REL, increase in dominance for the wife. |
      +-----------------------------------------------+
```

Figure 3-3: Planning graph for the wife's first statement. The effects of the ACCUSATION are already achieved by the time this level is processed.

When the EX-EMOTION goal is processed, the first planning step now has a new phase. Effects of the plan, here EMPH(asize), are checked against the table of effects from the first plan. It is always possible, and often happens, that the desired effects have already been achieved as side effects of a previous plan. If this is the case, further realization planning is not necessary. Here, the desired effects of the EX-EMOTION goal will not necessarily be achieved by the QUESTION plan. Thus, the realization phase is begun.

When a goal is later in a queue, the realization rules operate differently than if it were first. The task of the realization rules now will be to EMPHASIZE an aspect of the utterance prototype. In isolation, the EMPH plan might produce an exclamation or expletive. But constrained by the sentence prototype, the emphasis must be on a concept already slated for expression. There are basically 4 choices for emphasis of concepts in the utterance "Why were you out late last night."

1. Why the hell were you out late last night?
2. What were you, of all people, doing out late last night?
3. What were you doing out so late last night?
4. What were you doing out late last night, of all nights?

The choice depends on what the most important aspect of the modified concept is. This can be found by tracing back to the source of the anger, which turns out to be the schedule violation. Thus, time is tagged with an emphasis marker in the first modification of the prototype utterance.

The final goal, D-REL, has given rise to a plan to accuse the husband of wrongdoing. The necessary effects of this accusation are that the husband know that the wife is upset and that she knows about the schedule violation. Also, the wife hopes to make the husband feel guilty and perhaps force him to tell her where he was. A check of the effects already achieved by the utterance in its present form shows that all of the desired effects have been achieved. In this case, no modification of the utterance is necessary and so the application of further realization rules is not needed. The utterance stays as it was after processing EX-EMOTION goal, "Why were you out so late last night?." Since there are no further goals to process, this is the final form of the wife's first utterance.

As a further illustration of the multiple goal planning mechanism, consider the generation of the wife's second statement, "I thought you hated bowling," 3-4. (Again, the effects shown are expected to occur in the husband.) The planning graph is quite similar to the graph in Figure 3, but now the first goal is different. In this case, the wife's initial reminding of her husband's attitude toward bowling has triggered the detection of an inconsistency in memory. between her husband's stated activity and the negative attitude she knows he has about bowling. The inconsistency has in turn suggested that the husband might be lying. This has made the wife more angry (goal 2) and has resulted in a third goal to gain dominance back in the relationship by forcing an admission of lying.

```
1) KS-SEEK:   Husband's stated activity: bowling,
   |          husband's negative attitude toward bowling.
   |
   +- plan -> KS-TRANS: Memory token.
              |
              +- realization -> STATE: "I thought you hated bowling. <-+
                                |                                      |
                        effects |                                      |
                                v                                      |
     +-----------------------------------------------+                 |
     | KS:  Wife knows Husband hates bowling.        |                 |
     |      Wife detects inconsistency.              |                 |
     +-----------------------------------------------+                 |
                                                                       |
                                                               modify  |
2) EX-EMOTION: Anger.                                                  |
   |                                                                   |
   +- plan -> EMPH: Source of anger: inconsistency.                    |
              |                                                        |
              +- realization -> EMPH incons: "I thought you hated -----+
                                |               bowling!"              ^
                        effects |                                      |
                                v                                      |
     +-----------------------------------------+                       |
     | EM:  Wife is suspicious.                |                       |
     |      Husband is guilty.                 |                       |
     | REL: D+REL, Wife gains dominance.       |                       |
     +-----------------------------------------+                       |
                                                               modify  |
                                                                       |
3) D-REL: Wife gains some dominance back in the relationship.          |
   |                                                                   |
   +- plan -> ADMIT: Husband admits to lying.                          |
              |                                                        |
              +- realization --> ACCUSATION: ("I thought you hated  ---+
                                 |             bowling!")
                         effects |
                                 v
     +-----------------------------------------------+
     |*KS:  Wife knows Husband hates bowling.        |
     |*EM:  Husband is guilty.                       |
     |      (Wife is angry.)                         |
     |*REL: D+REL, increase in dominance for the wife. |
     +-----------------------------------------------+
```

Figure 3-4: Planning graph for the wife's second statement. The effects of the ACCUSATION are already achieved by the time this level is processed, thus no direct ACCUSATION is made.

The goals are again processed in order. The plan to tell the

husband about the inconsistency is initiated and realized by bringing up the inconsistent memory token (the husband's negative attitude). Since he just stated that he went bowling, she knows that he has forgrounded the activity. So when she states her memory of his attitude, it will be clear that an inconsistency is at issue.

Secondly, the anger expression goal is processed. As before, the plan to add emphasis is adopted. It will modify the prototype utterance, "I thought you hated bowling." In this case, however, there is not a particular aspect of the prototype which needs emphasizing. Tracing the source of the anger back, the realization rules find that it was caused by the inconsistency in the first place. Since it is the inconsistency which is being expressed in the utterance already, the entire statement is modified. The effects of such an emphasis, as before, are to inform the other person about the wife's emotional state, perhaps to make the husband feel guilty himself, and to gain some dominance for the wife.

Finally, the ACCUSATION plan is pursued. The desired effects have again been achieved, however. Thus no realization rules are applied and the utterance remains the same. When all of the active goals are exhausted, the utterance is complete.

3.3 Producing Alternative Statements

The range of alternative statements that are appropriate at any given point during a dialog seems quite large. We propose that one possible reason for this is that conversants are simultaneously acting

on variety of goals at many levels. How does the presence of many goals in our system lead to the generation of alternative responses?

Active conversational goals are processed in order. Again, the order is intended to reflect the relative importance of each goal. By changing the order, we are able to generate alternative appropriate responses.

Consider again the first utterance, "I thought you hated bowling." If the D-REL (dominance) goal had come first, then the prototype sentence might have been something like, "You were out with someone else last night." The emotion goal would have emphasized the time element, "You were out late with someone else too late last night.". Finally, the KS-SEEK goal, all of the desired effects of which would not have been satisfied by this time, would modify the statement into something like, "You were out late last might with someone else, weren't you?"

If the goal order had been EX-EMOTION, D+REL, and KS-SEEK, then the prototype sentence might have been "Damn you!", the first modification, "Damn you, you were out too late last night.", and the final modification might have been, "Damn you, you were out too late last night. Where were you?" In the next section, we will explore some possible next statements for the first two statements in the context of alternatives that human subjects provided us when shown the husband and wife conversation. We should be able to account for their alternative statements by reordering our goals. Also, we will see how well their answers to questions about why the statements in the conversation were

made correspond to the conversational goals we have proposed here.

4. **Psychological Evidence**

To test some of our intuitions about the goals present at various times during the husband and wife dialog, and to provide the material for implementing the potential for planning possible next statements, we gave the conversation to a group of 17 human subjects. We asked them first to read through the conversation and then go back and answer three questions about each statement (females answered for the wife's statements and males answered for the husband's statements). The questions were:

1. Why did the wife/husband say that?

2. What is the wife/husband trying to say or do?

3. Write down three alternative responses that the husband/wife might make to this statement.

Answers to the first two questions should provide some data that bears on the question of conversational goals. Will subjects agree with us on what the motivations of the husband or wife are? Since the two questions seem to be identical in terms of the types of answers they elicited, we lumped them together and will refer to this collection of responses as "reasons." The alternative responses given for question 3 should be responses which are plausible output from a reordered set of the conversational goals we used or reasonably easily assimilated into our system. We will present data on the first two statements of the wife (since we have concentrated entirely on the wife throughout this paper). We did not collect alternative responses for the wife's first

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statement, however, since it is not really a response.

When discussing particular reasons and alternative responses in subsequent paragraphs, we will generally report both the percentage of subjects who gave that particular answer (%S's) and the percentage of total answers for which that answer accounts (%A's). For example, 6 out of 8 subjects (75% S's) may have given the same answer to a particular question, and that answer may account for 5 of 10 answers given to that question (50% A's). Such a response should be considered more likely to occur in a conversation, and is more important in terms of worrying about implementation, than an answer which was given by only 1 out of 8 subjects (12.5% S's) and which is only 1 of 10 answers given (1% A's). Since no two subjects gave the same exact answers, subjective judgments about when two answers were the same had to be made. For the most part we think these judgements will be non-controversial, and for our purposes here greater rigor is not required.

4.1 The Wife's First Statement

Subjects' answers to the motivation questions about the first statement, "Why were you out so late last night?," provided strong evidence for the validity of our major goals - KS÷SEEK and EX-EMOTION. Summarizations of their reasons and the goals they correspond to are shown in Table 4.1. Seven out of the eight subjects (87.5% S's) said that the question was asked simply to "find out what was happening" or because of "curiosity". These answers accounted for over half of all the answers given to the motivation questions (7 out of 13, or 53.8% A's). Two out of the eight subjects (25% S's, 15.4% A's) also said that

the wife was angry when she asked her husband why he was out so late, tending to justify our use of the EM-EXPESSION goal. Another 3 subjects (37.5% S's, 23.1% A's) said that the wife was suspicious and that she wanted to see if her husband would lie about or admit what he had done. We did not take this more radical view in our program, though we could have. We assumed instead that the wife was not suspicious in the beginning and waited until her husband's later comment about bowling and the inconsistency it triggered to activate suspicion and a plan to get him to admit to a wrongdoing.

Statement: "Why were you out so late last night?"

Reasons	Freq	Goals or Plans	
Force him to admit.	1	ADMIT	21%
She's suspicious. To see if he'll lie.	2		
Find out what was happening. Curiosity.	7	KS-SEEK	58.3%
Bully.	1	EX-EMOT	21%
She's angry.	2		

Table 4.1. Reasons given by subjects for the wife's first statement.

We did not ask subjects to give us alternatives for the wife's first statement. The first statement in a conversation seems to be open to fewer options than other statements since the speaker generally has a very specific objective and there is no prior context from the dialog to help provide alternative paths.

4.2 The Wife's Second Statement

Again, for the second statement, "I thought you hated bowling," subjects tended to agree with our analysis of the goals present or the important precipitating beliefs. All of the subjects agreed that the

belief that the husband is lying plays a part in generating the wife's second statement (93% A's). We generated the ADMIT plan in our analysis from the memory inconsistency (something the subjects couldn't really have known about). Five subjects (62.5% S's, 33.3% A's) said that the wife was trying to get her husband to admit to a wrongdoing. Of the remaining motivations in this category, two are reminiscent of the lying theme but focus on it indirectly. They describe strategies more than motivations. One suggests a strategy of making the husband feel "guilty". This is an effect of the STATE-INCONS realization in our analysis. One other reason response suggests that the wife's statement is a strategy to undermine the husband's remark by pointing out that "it is a bad excuse". The guilt strategy again lends support to our use of ADMIT, but via a different set of realization rules than guided us. There is no reason to believe (and every reason not to) that the same conversational behaviors can be motivated by different goals, and that the same goals can be derived via different strategies.

Two subjects (25% S's, 13.3% A's) agreed with us that the wife is continuing to vent anger with this remark. Two other subjects gave reasons for the wife's statement which do not coincide at all with our current implementation, but which can be accommodated theoretically. They suggested that the wife simply wanted to know if her husband suddenly likes bowling. That is, they suggested a pure KS-SEEK goal with no overriding context effects.

Statement: "I thought you hated bowling."

Reasons	Freq	Goals or Plans	
Point out that it was a bad excuse.	1	ADMIT	66.7%
She knows he's lying. She doesn't believe him.	3		
Push him into telling the truth. ADMIT	5		
Get him to feel guilty.	1		
Find out if he really hates it.	1	KS-SEEK	20%
Curiosity.	1		
Innocence.	1		
Vent anger.	2	EX-EMOT	13.3%
Alternatives			
Did you win? How did you do?	4	KS-SEEK	40%
Was it fun?	2	(Alone)	
I know you weren't bowling. I don't believe you. Bull.	2	KS-INCONS + ACCUSE	26.7%
Are you sure?	1	KS-INCONS	
Bowling doesn't go all night!	1	Focus:late	13.3%
Why so late?	1		
I wish you'd taken me along.	1	D-REL(Compny)	6.7%
What's wrong with our marriage.	1	D-REL(Source)	6.7%
I was just asking.	1	End Conv.	6.7%

Table 4.2. Reasons and alternatives for the wife's second statement.

The alternative responses given by subjects for the wife's second statement are shown in the bottom of Table 4.2. With the three goals present at this time in our analysis, there are 3 possible alternative responses, depending on the order (See Chapter 4).

1. KS-INCONS + EX-EMOTION + ACCUSE => "I thought you hated bowling!"

2. EX-EMOTION + KS-INCONS + ACCUSE => "Damn you! I thought you hated bowling."

3. ACCUSE + KS-INCONS + EX-EMOTION => "You liar, you hate

bowling!"

Something like response 3, calling the husband a liar, was included by six subjects. Four of them (44.4% S's, 26.7% A's) thought a direct accusation would have been appropriate, "I know you weren't bowling", "I don't believe you", "Bull", and "Are you sure?". The other two (22.2% S's, 13.3% A's) suggested a focus on the lateness of the hour, "Bowling doesn't go all night" and "Why so late?". This type of response would occur if the ACCUSATION had come first, modified by the EX-EMOTION goal.

Subjects suggested that questioning the goal fulfillment was a possible response at this point in the conversation, with six (66.7% S's, 40% A's) suggesting alternatives like "Was it fun?", "Did you win?", and "How did you do?". These responses suggest that the wife did not suspect her husband of lying. To create this situation, we would eliminate the KS-INCONS CTP, and instead generate a KS-SEEK goal. In the absence of other factors, like lying or suspicion, asking about the goal of a stated activity seems like a likely, purely casual, thing to do. In this instance, such responses seem out of character with the situation.

One of the subjects (11.1% S's, 6.7% A's) produced a response compatible with an expression of the relationship goal subsumption failure caused by the husband's staying out too late, "I wish you'd taken me along". This is a response to the schedule violation and resulting ACCUSATION plan of wrongdoing. If a memory inconsistency had not been uncovered, the ACCUSATION from statement one would have been

left over and this type of response could be produced. However, it is clear that the ADMIT context has taken a stronger role than the original, still overriding D+REL goal from the wrongdoing. One other subject suggested that the wife go right to the source of the D+REL goal in the first place, "What's wrong with our marriage?", a feat that our program (and most people) can't yet perform. Finally, one person suggested a response that is most likely designed to end the conversation while expressing some kind of emotion at the same time, "I was just asking". We will be forced at some point to deal with these kinds of "conversation monitoring" statements - perhaps even devising a set of conversation monitoring goals.

4.3 Some Observations from the Data

In general, we were able to explain many of the alternative responses that subjects gave within our goal scheme. The alternatives suggest a number of programming experiments that should be tried. In particular, the responses suggest experiments with removing different goals as well as reordering. The data collected here are more useful in constraining future directions that the system might go than in demonstrating the validity of what has already been done. However, they do seem to suggest that the goal oriented approach to conversation as it is discussed here is a step in the right direction. A number of issues have yet to be addressed, in particular the questions of focus, conversation monitoring mechanisms, the range of dialog acts, and how to plan complex dialogs. Here we have tried to address the related questions of alternative statements and goal interaction. The need for

more specific experimentation, both in the psychological and computational areas is very apparent since much of the current effort has the flavor of overgeneralization from too few examples. It hard to judge whether or not the ability of our model to capture many of the alternatives generated by subjects is due to a good model or a clever analysis. The expansion of this project into other dialog contexts (and to the end of this dialog of course) will help to fill out the details of the overgeneralizations herein.

We are currently conducting an experiment in which the number of conversational goals which motivate statements is varied. If subjects process multiple goals in the way we propose, then it should take longer to read and understand multiply-motivated statements, and they should be more memorable, than statements motivated by a single goal. Preliminary results confirm our hypothesis.

5. An Annotated Example

This section consists of an annotated run of the MAGPIE program. The conversation is at the following point:

<wife home alone last night, husband out somewhere>
W0: WHY WERE YOU OUT SO LATE LAST NIGHT?

H1: I went bowling with the boys.

The husband has just asserted H1 shown above. The program will generate a response to this assertion. Trace messages from the knowledge state tracker, the truth and trust tracker, and the relationship tracker are shown along with messages from the planner. These are the levels that are relevant in processing this statement. The parsed input is shown below.

```
*!INPUT
(M-BOWLING BOWLER-A (HUMAN INSTAN (PETEO))
           BOWLER-B (HUMAN INSTAN (FRIENDSO))
           TIME (*PAST*)
           EVENT (EV-BOWL))
```

The parser has successfully accessed the bowling MOP (M-BOWLING) and determined that its main event (EV-BOWL) has been referenced. The next block shows the rest of the knowledge state tracking.

```
*<KS>*  Building New Episode for MOP: M-BOWLING
*<KS>* Inferring Setting: ALLEY

*<KS>* COMPLETE EXPLANATION EPISODE SEARCH

*<KS>*  Considering Expectations from EP2
*<KS>*  Considering Expectations from SCENE2
*<KS>* Event:  EV-BOWL in M-BOWLING

*AG* RULE: ENTERTAINMENT CONSTRAINT  ** FAILED **
*<KS>* INCONSISTENT ENTERTAINMENT GOAL:  E-ENTERTAINMENT IN M-RECREATION

==>*<KS>* Instantiating CTP: Plan Inconsistency
```

```
************** CEP: KS-PI0 **********************
* CLAIM: G-HAVE-FUN-A0                          *
* MEMORY: ATT9                                  *
*                                               *
*************************************************

*<KS>*  Considering Expectations from KS-PI
*AG* RULE:  ATTITUDE EXPLANATION RULE  ** FIRED **

=*>*<KS>*Instantiating Conv. Goal: KS-SEEK2
************** CONV-GOAL: KS-SEEK2 **************
* ACTOR: WIFE0       OBJECT: ATT9               *
* SPEC: VERIFY                                  *
*************************************************
```

The next block shows the representation generated by the truth and trust tracker. The lie is detected as a possible explanation to the inconsistency detected at the knowledge state level. The rule that fires here is as follows:

```
KS-INCONSISTENCY RULE
    IF
       there is an inconsistency at the knowledge state, and
       there is competition (an argument) between the
        conv. goals of the speaker and the listener, and
       the speaker is not completely trustworthy,
    THEN
       assume that the speaker is lying.
```

```
*<T&T>* SCRUTINIZE RESPONSE
*AG* RULE: KS-INCONSISTENCY   ** FIRED **
*<T&T>*

=*>*<T&T>* Instantiating LIE
****************** LIE0 *************************
* CLAIM: EP2         CAUSE: KS-INCONSISTENCY0  *
*                                               *
*************************************************
```

The next block shows the messages from the relationship tracker.

An attitude inconsistency CTP (REL-AI) is generated since husbands should not lie to their wives. This leads to the acquisition another conversational goal to regain lost dominance in the relationship.

```
----------------------------------------------------------------

*<REL>* RELATIONSHIP:  R-MARRIAGE0
*<REL>*  Considering Expectations from R-MARRIAGE0

*AG* RULE: TRUTH RULE    ** FAILED **
*<REL>* INCONSISTENT ATTITUDE: TRUST

==>*<REL>* Instantiating CTP: Inconsistent Attitude
************* CTP: REL-IA0 ********************
* VICTIM: WIFE0       LOUSE: HUSBAND0            *
* GOAL: G-S÷COMPANY-HUS0                         *
*                                                *
**************************************************

*<REL>*  Considering Expectations from REL-IA
*AG* RULE:  DISHONESTY RULE ** FIRED **

==>*<REL>*Instantiating Conv. Goal: D+REL2
************* CONV-GOAL: D-REL2 ****************
* ACTOR: WIFE0        OBJECT: DOMINANCE          *
* RELATINSHIP: R-MARRIAGE0                       *
**************************************************

----------------------------------------------------------------
```

The next block shows messages from the planner. The response "I thought you hated bowling" is generated in pursuit of three conversational goals:

1. D+REL2 -- a relationship dominance seeking goal,

2. EM-EXPRESSION3 -- an emotional level anger expressing goal,

3. KS-SEEK2 -- a knowledge seeking goal (to further explain the attitude inconsistency).

4. The planner must also processes a few other active goals left over from the first statement in the dialog. However, for

simplicity, we have deleted the trace messages from this processing.

```
==>** ENTERING PLANNING PHASE **

*G* ---- FACTOR: KNOWLEDGE-STATE  = (KS-SEEK2)
*G* RUNTIME GOAL Search on KS-PI0
*G* Prototype evaluation: KNOWLEDGE-STATE
*G* PLAN:  KS-TRANS
*G* Prototype is an INCONSISTENCY
*G* Generator Statement of memory being created
*G* New Generator Concept:
         ((PLEASURE ACTOR HUSBAND0
                    :OBJECT EV-BOWL
                     SCALE -10)
          (IS MLOC ACTOR WIFE0))

*G* ---- FACTOR: EMOTION = (EM-EXPRESSION3 EM-EXPRESSION2 EM-EXPRESSION1)
*G* RUNTIME GOAL Search on ANGER2
*G* RUNTIME GOAL Search on JEALOUSY0
*G* RUNTIME GOAL Search on ANGER1

*G* ---- Entering RUNTIME GOAL net:  EM-EXPRESSION3
*G* Checking the OBJECT of: EM-EXPRESSION3
*G* Emotion is ANGER, checking Scale
*G* PLAN:  EMPH
*G* Moderate anger, modifying Generator Concept
*G* New Generator Concept:
          (*!* ((PLEASURE ACTOR HUSBAND0
                          :OBJECT EV-BOWL
                           SCALE -10)
                (IS MLOC ACTOR DONNA0)))

*G* ---- FACTOR: RELATIONSHIP = (D-REL2 D+REL0)
*G* RUNTIME GOAL Search on REL-IA0
*G* Prototype evaluation: (KNOWLEDGE-STATE EMOTION)
*G* PLAN:  ACCUSE
*G* Effects Satisfied
*G* New Generator Concept:
          (*!* ((PLEASURE ACTOR HUSBAND0
                          :OBJECT EV-BOWL
                           SCALE -10)
                (IS MLOC ACTOR DONNA0)))

==>*G*  FINAL GENERATOR CONCEPT:
          (*!* ((PLEASURE ACTOR HUSBAND0
                          :OBJECT EV-BOWL
                           SCALE -10)
                (IS MLOC ACTOR DONNA0)))
```

---

6. Conclusions, Criticisms, and Future Directions

We agree with other dialog researchers that a proper model of a conversant must involve a planning procedure that generates responses in accordance with conversational goals. The thesis of the research described here is that conversational goals are not limited to pursuing the transfer of information at the knowledge state level only. Communication at the emotional, relationship, and attitude levels (as well as some others) is also prevalent in the pursuit of many conversational intentions.

The MAGPIE system is a computer model of a conversant that tracks communication at many such levels and deals with conversational goals at these levels accordingly. Specifically, we have describe in some detail procedures for tracking two of the levels: the knowledge state tracker and the relationship tracker. These procedures are typical of the MAGPIE tracking algorithms in that they rely on searching memory to find relevant knowledge structures. Such knowledge structures encode the rules and expectations which are at the very center of the MAGPIE program.

The conversational trace point has been introduced as one mechanism by which expectation and rule failures can lead to the acquisition of new conversational goals. As an example, the target husband-wife dialog is initiated by failures at the knowledge state level and the relationship level. First of all, a failed expectation for the husband to be home leads to a knowledge seeking goal. The wife wants to know

where her husband was. Secondly, at the relationship level, a husband is expected to subsume his wife's need for companionship. But this rule is violated by the husband's absence. So another conversational goal, to regain lost dominance in her marriage, is acquired by the wife. She seeks to reprimand her husband for not fulfilling his obligation.

We have also considered strategies for pursuing conversation goals. By considering the effects of alternative plans at the each of the communication levels, we have devised a planning algorithm which will generate a single response that simultaneously pursues several conversational goals. As an example, "Why were you out so late last night?" not only seeks information at the knowledge state level, but it expresses anger at the emotional level and seeks dominance (via accusation) at the relationship level as well.

A goal-based approach to modelling conversation seems quite appropriate for dealing with a certain class of dialogs. This type of communication, which we shall refer to as goal-directed conversation, is typical in arguments between spouses, meetings between students and their teaching assistants, and dialogs between salespeople and customers. In dialogs such as these, the conversants are pursuing a fairly specific set of goals. Their verbal behavior seems to be quite consistent with strategies for pursuing these goals. The wife wants to reprimand her husband for his unfulfilled obligation. A student is often simply seeking facts from his teaching assistant. And a salesman is trying (often very persistently) to get the customer to buy a given

product.

However, this certainly does not tell the whole story. Not all conversation is so goal-directed. In many dialogs, the goals of the conversants seem to play a minor role with respect to the specific verbal exchanges that take place. A typical example of this is a luncheon conversation between various computer scientists that we recorded as part of a psychology experiment. In this conversation (described in [Robertson, Johnson, and Black 81]), the topic of discussion ranged from dieting and weight lifting to college socializing and fraternity initiations. The only apparent goals of the conversants were to entertain and to be entertained. Such goals are much more general than the sort we have described in this paper and it seems unlikely that the tracking and planning algorithms we have described would be of much use in such situations.

The recorded dialog was quite coherent. It consisted almost entirely of a continuous exchange of interesting experiences that the conversants described to each other. As the conversation proceeded, the participants were frequently reminded of past episodes that seemed apropos to the discussion at hand. And as each conversant related his interesting experience, another conversant was reminded of a similar episode that he had experienced and so on.

Coherency in such conversations seems to be more related to coherency in memory organization than it does to goal and plan processing. Our conclusion from this is that in order to develop a

general model of a conversant, it is necessary to equip the model with a rich set of experiences. These experiences must be organized in memory in such a way that they will be recovered during the natural course of understanding other conversants' statements. It is likely that conversation goals will provide an important index in searching such a memory, but other indices are likely to play a key role as well.

Our next step in the MAGPIE project will be to explore the indexing mechanisms that enable an understander to search memory. (An initial step in this direction is described in [Schank 81], chapter 10.) Our approach will be to build a large memory into our model, and to consider how slight variations in the husband-wife dialog might affect the searching process. Slightly different inputs are likely in many cases to lead to different remindings while searching memory.

Again, our primary research goal in developing the MAGPIE model is to explore the cognitive processes underlying conversation. We believe that modelling human conversants is likely to be the only way to develop a general system that can communicate with humans. To this end, we will continue to conduct our research by developing a computer model hand-in-hand with psychological experimentation.

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